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The Quality of Raw Cocoa as it Affects the Manufacturer

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Plant breeding programmes and tree selections will, in the near future, have a big effect on the type of cocoa production in the world. Large-scale units are already in existence which propagate annually tens of thousands of new selections by clonal methods. Accordingly, trees selected for yield and agricultural qualities may soon fill large areas with one or two clonal varieties. This constitutes a major change in the methods of propagation which will more rapidly affect the type of cocoas in the larger producing countries of the world. New areas now being exploited will give much more uniform cocoa than has ever been known in the past, and manufacturers, under these circumstances, may be denied any great variation in the choice of the cocoas they purchase.

These developments serve to emphasize the necessity for careful selection of trees to be propagated. Since the basis of the cocoa and chocolate industry is purely the satisfaction of the public taste, the flavour properties of the beans produced from selected trees is of paramount importance, but there are many other factors which seriously affect the manufacturer and which need special emphasis. Manufacturers are the direct purchasers of cocoa and it is to their requirements that the planter and farmer must work. The research worker and the planter must understand fully the types of cocoa required by manufacturers. This article is an effort to explain the fundamentals and variations of the cocoa required which in the past have seemed so puzzling to those working in the tropics, far away from the users of their crop.

TYPES OF COCOA

There are three generally recognized types of cocoa. The first is Criollo, by which is understood the type which produces beans with cotyledons which are white when taken straight from the pod and on fermentation change to a pleasant cinnamon brown. These beans have a characteristic flavour peculiar to themselves and are used in special productions only. The amount grown in the world is very small—approximately 5,000 tons. Since the trees which produce the cocoa are delicate and prefer to grow at an altitude of 2–3,000 feet, the production is falling. The quantity at present produced cannot be considered of any serious consequence.

The second type is known as a flavour cocoa. Its varieties come from Central America and the West Indies chiefly, and they have flavour characters which are prized by some manufacturers. The production, though greater than that of the Criollo cocoa, is only in the neighbourhood of 50,000 tons per annum. Because of their strength of flavour, manufacturers use these cocoas admixed with those of the Amelonado type.

Most of them sell on their flavour characters and are selected on sample. Consequently, manufacturers have their own views on flavour and different buyers look for different characters according to the type of chocolates they produce.

The third type may be called the ' bread and butter ' cocoas and are classified generally under the name of Amelonado and are not so selective in the areas in which they grow. The main producing countries of the world are West Africa and Brazil. This type is also gradually superseding the first two types in many parts of the world. It is the only cocoa which can be said to be increasing in tonnage. Many of the areas in Asia which 50 years ago grew pure Criollo, are now mainly producing Amelonado or its hybrids.

THE USE TO WHICH COCOA IS PUT

The basic use of the cocoa bean is the manufacture of cocoa and chocolate. They are two interdependent products. The first is mainly used as a drink but also as a flavouring agent in cakes, puddings and other similar household commodities. Chocolate, besides being itself a very popular sweetmeat, is used as the covering to ice-cream, biscuits, cakes, *etc*, to increase their acceptability to the public.

During the manufacture of cocoa powder part of the fat is removed by pressure from the ground nib. This fat is used in the preparation of chocolate where the addition of sugar and/or milk to the ground nib makes a paste far too stiff to mould into blocks and bars, or to flow easily as a covering. The thinning of this paste by the addition of cocoa butter is essential for rapid and easy moulding on modern machines. Where chocolate is used for covering confectionery, greater additions of cocoa butter are necessary.

The addition of lecithin to chocolate, by its capacity for increasing fluidity, has reduced considerably the amount of cocoa butter required in their manufacture. The demand for cocoa butter remains, however, in excess of that produced from the manufacture of cocoa.

Thus fat-free fibre becomes almost a waste product but it contains approximately 3 per cent of theobromine which is a valuable commodity in medicine. Theobromine can readily be converted to caffeine for which there is a large demand. Caffeine is present in a number of other plants such as coffee and tea, and the manufacture of synthetic caffeine has already been carried out. Cocoa, however, is the only source of theobromine known at present.

Thus there are four interdependent uses for the cocoa bean:

(*i*) The manufacture of drinking cocoas.
(*ii*) The manufacture of eating chocolate.
(*iii*) The manufacture of cocoa butter.
(*iv*) The manufacture of theobromine.

Some of these are mutually exclusive if we consider the desirable qualities of the cocoa beans in relation to each of these uses.

It is clear that the ideal cocoa bean (*i*) has a good chocolate flavour developed on roasting, (*ii*) has a high fat content, (*iii*) has a high theobromine content. This latter may not necessarily be very desirable in cocoa

and chocolate, so that the ultimate source of theobromine might be from waste products such as the shell of the bean by some new process giving superior recovery to those at present in use.

Research has not yet shown what substances are responsible for the flavour of cocoa. We know nothing of the precursors of flavour or the form of their inheritance; such work is only beginning but we do know that fermentation of the bean is a vital stage in the production of flavour.

There are many areas where cocoa is said to have deteriorated greatly during the last 15 years. This seems to have occurred more in the New World than in the Old. It is, however, impossible that the tree population should have changed significantly in so short a time. In some areas, certainly, new types of cocoa have been planted. Even so, this could not yet have changed significantly the general character of the whole crop. It is far more likely that a change in the method of preparation is the cause.

There are significant facts which point in this direction. Plantations with excellent reputations for the quality of their product have, during the period from 1939 onwards, produced cocoa of inferior quality.

Where peasant populations prepare cocoa on a comparatively small scale it is an observed fact that occasionally farmers will produce excellent cocoa, quite outstanding for the area.

There is only one explanation for these facts and this is that the preparation has been responsible for the variations and not the tree population.

This all lines up with the known facts that there are great variations in the practice of cocoa preparation in the tropics and it emphasizes the importance of adequately controlled methods if a standard commercial article is to be provided.

VARIATIONS AND THEIR EFFECT ON THE MANUFACTURER

What are the difficulties produced by the various defects originating in inadequate preparation of the bean in the tropics and the effects on the manufactured product ?

Unfermented Cocoa

These are beans which have been little more than dried in the sun as soon as they are removed from the pod. They are the ' slaty ' beans of commerce. Their appearance is generally a slate-grey. Under a low-powered magnifying glass a cut surface of the bean appears mottled with dark spots of undistributed colour. The texture of the cotyledon is leathery and the cotyledons are closely packed together.

This defect is mainly one of the peasant producers and is most likely to occur in excess in new areas. A few such beans are found in the production from all areas and appear to be due to the practice of adding to the fermenting heaps beans taken from odd pods which are not sufficient in quantity to ferment by themselves. Such beans added on the last day of fermentation find themselves on the drying trays within 24 hours of the pod being opened, and thus have no fermentation at all. The practice of adding fresh beans to heaps already in the course of fermentation, at whatever stage this occurs, has a bad effect on the product.

Unfermented beans do not produce a chocolate flavour on roasting. Since this operation is controlled by the odour developed, and time and

temperature cannot be the only guide, a roaster would find it difficult not to burn a batch of unfermented beans before he realized that the usual cocoa odours are not going to be produced.

The shell in unfermented beans adheres closely to the cotyledons and in the winnowing process is most difficult to separate. It is, in fact, impossible to carry out the separation properly and much shell will find its way into the nib clinging tightly to its surface. Many countries today have strict regulations as to the amount of shell permissible in cocoa products and these could not be complied with if unfermented beans were used.

The texture of the cell walls of unfermented cocoa is leathery and quite unlike that of the brittle, well fermented bean. This causes the manufacturer more trouble. Grinding is slow and difficult and the output of machines falls greatly. The release of the fat from the cells being incomplete, more cocoa butter is necessary to get the same fluidity for factory handling. These facts alone can considerably increase the cost of production.

The fat content of the nib of unfermented beans is approximately 2 per cent lower than from well fermented beans. This also is a serious defect as fibre and fat are already in an unbalanced position, with fat as the deficient partner.

However, the most important defect is the lack of chocolate character and the objectionable nature of the flavour developed by roasting. The colour of chocolate from unfermented beans is a blue-grey rather than a chocolate brown. The flavour is bitter and astringent, roughening and drying the palate, with an earthy, herbal background. It is, in fact, a commodity which would appeal to none and even in small quantities imparts a background flavour which is easily detectable.

No manufacturer could make chocolate from unfermented beans. The presence of even small proportions affects the quality of the manufacturer's goods very considerably. Their only use, therefore, is for the extraction of cocoa butter and the manufacture of theobromine.

Purple Beans

There are various defects possible when fermentation has been imperfectly carried out. Unless times and temperatures are observed many different flavours can be developed. To the buyer, attempting to assess quality by observation only, colour is an important guide. Naturally, this only produces reliable assessments where the method of preparation has been the traditional one of fermentation.

Purple beans indicate inadequacy of preparation; chiefly that the temperature of the fermenting heap has in the later stages been too low, or in the early stages too high. These variations produce other flavours the character of which depends upon the details of fermentation. The chief of these are bitterness, floral and liquorice flavours.

Roasting will affect the purple colour considerably but only a mild chocolate flavour can be produced. This, accompanied by various flavour characters, will prevent manufacturers from developing the standard chocolates for which their names stand. Thus the variety of flavours produced makes this defect a difficult and objectionable one.

Germinated Beans

These are largely the defect of peasant producers. Those beans in which the radicle has grown to any great extent are not put in the fermenting heap, or are picked out after fermentation, but there are still a small percentage in which growth has only just been sufficient to enlarge the micropyle to a definite hole. The greatest objection to the presence of even a small percentage of these beans is the fact that they allow and encourage the breeding of insects. A very large proportion of these beans are insect-attacked and together with broken and cracked beans are the chief means by which an insect population maintains itself in cocoa. Cocoa beans with intact shells are seldom attacked seriously by insects. Here, attention should be drawn to the increasing legislation against insects in foodstuffs so that this defect will be of increasing importance as more countries become insect conscious. Moulds can also enter the bean through the open micropyle and so produce that most disastrous defect, mouldy cocoa.

There is little information on the effect of germination on flavour. What little is known suggests that the beans are mild in flavour, lacking good chocolate character.

Mouldy Beans

By far the worst defect is the presence of mould. It is not always easy to distinguish accurately the flavour effect of moulds which show on the outside of the shell and those growing on the cotyledon itself. Normally, those on the shell have little significance. Occasionally, however, they penetrate the shell in a form which cannot be observed with the naked eye, but which affects the flavour of the cotyledon. It is equally true that visible moulds inside the shell are not always related to objectionable mouldy flavours.

Moulds inside the bean increase the free fatty acid content of the cocoa butter and can make refining of the fat essential before it can be used.

It is frequently overlooked that mould development in the bean can increase the liability of the manufactured goods to develop moulds under poor storage conditions.

The most objectionable of the characters developed is that of flavour. These flavours are completely unaffected by the processes of manufacture. They render the fibre portion of the cocoa unusable; the fat must be refined before it can be used which, apart from the expense, produces completely odourless fat suitable only for specialized uses. Amounts as low as 4 per cent of mouldy beans can be detected by taste in a sample of chocolate which has passed through all the normal manufacturing processes.

Although fermenting heaps always contain moulds, these rarely affect the flavour or enter the shell. Only in the case of germinated beans is this likely to occur seriously. Most of the mould growth which affects flavour occurs either during the drying stage when this is unduly prolonged, or develops on the beans during storage in unsuitable places. Storage is probably the cause of most of this defect, especially in the tropics. Atmospheric humidities of over 80 per cent will cause mould to grow on beans, and beans with a moisture content of 8 per cent or over will fairly rapidly mould.

Storage in the country of origin where the atmosphere is damp and warm should be avoided as far as possible. The surface of the bean contains innumerable spores, and mould growth, therefore, is very rapid when cocoa is once wetted externally. The shell of cocoa can absorb its own weight of water without appearing damp to the eye, so that appearances as to dryness are often very deceptive.

POD DISEASES

There are a few pod diseases which affect the beans if they are left to develop. Amongst these blackpod is by far the most serious. This disease quickly penetrates the pod and attacks the sweet pulp surrounding the seeds. Here it lives on the sugar in which the fermenting organisms grow. Thus such beans added to a fermenting heap do not add anything but bulk and consequently reduce the temperature of the fermenting heap, and are conducive to the production of purple beans. Still more serious is the attack on the bean itself. The fungus rapidly penetrates the testa and lives on the glycerine of the cocoa butter, increasing the free fatty acid content. Fat pressed from beans taken from pods heavily infested with *Phytophthora palmivora* has been found to contain up to 40 per cent of free fatty acids. Such cocoa butter cannot be used until refined, which in the worst cases can reduce the yield of fat to a half.

Thus this disease resembles the characteristic mould which develops in the beans during preparation and storage, and can be as objectionable.

The flavour produced from beans which have suffered attack by blackpod is unlike chocolate, suggesting a mixture of earthiness and mould. Beans attacked by this disease are seldom used in Nigeria where they are known as ' velvety ' beans. It is an offence to include diseased beans, and parcels containing them are returned to the seller to be picked over.

BROKEN BEANS AND INFESTATION

In some countries beans are washed to such an extent that the shell is made thin and brittle. Under such conditions much of the cocoa is broken during handling and carriage. When the manufacturer cleans and grades such beans for size the number of whole beans produced is small. Broken and brittle beans produce much waste and make the separation of extraneous matter difficult. Roasting can only be carried out on beans of a reasonably equal size and even roasting of broken nibs is not always possible. Therefore the broken section of a consignment has naturally to be used for the less expensive lines, thus considerably reducing its value.

An even more important aspect of broken beans is that this is material which is responsible for the maintenance of the population of insects in a cocoa sack. Whole beans are almost immune from attack and if it were not for this broken residue which, even in unwashed and well prepared cocoa often amounts to 0·5 per cent, and the germinated and washed beans, the insect population would almost disappear. As mentioned above, the world is gradually becoming more and more insect-minded and the presence of insects in raw materials is proving more and more an embarrassment to manufacturers.

Care in handling cocoa is of great importance.

SHELL PERCENTAGE

Shell is purely a by-product to the manufacturer. He can get at best but a few coppers for it, and often he has to pay for it to be carted away and burned. The difficulty is largely that fillers in animal feeds are cheap and abundant in supply and most of them are more suitable for this purpose than cocoa shell. Shell contains about 1 per cent of theobromine which is dangerous when fed to birds and is unsuitable for young animals. The amount of theobromine in shell is not high enough to make it profitable to extract, but is too great to be ignored in animal feeds. Shell will absorb 300 per cent of water and this is another property which creates difficulty when used as a feeding stuff. It has been used successfully as an accessory fodder on account of its Vitamin D content.

Shell has therefore little to recommend it as an article for commerce and is practically useless. The only useful function which it appears to perform is to protect the valuable nib during transit. The percentage of shell on a bean is an economic consideration in the purchase of cocoa and everything should be done to reduce it to the minimum.

The shell content of beans varies greatly. A fine, washed Samoa or Ceylon will have as low as 8 per cent, whilst West African cocoa has between 11 and 12 per cent. The cocoas of the Americas are higher and Trinidad cocoa is usually 14 per cent, while some of the South American cocoas have been as high as 16 per cent. More work is necessary on determining the actual percentage of shell on the original bean and how much it is increased by preparation and other factors. It is well known that at one time claying was a common practice in the New World and as much as 3 per cent has been added on occasions. The clay gave the bean a pleasant, even appearance and served to hide many defects ! Unfermented beans have a lower shell percentage than fermented. The bean from the pod has a shell percentage of something like 10 per cent and this increases during preparation. Much of the increase seems to be due to micro-organisms which grow in the fermenting box and cling to the shell during drying. This can possibly increase the percentage of shell on beans by up to 2 per cent. Undoubtedly some weight is also picked up from the drying floors in the form of dust and earth which could add another 1 per cent to the shell percentage. When drying is slow mould continues to develop and this appears not inconsiderable as a further addition to the weight of shell. Apart, therefore, from any variations due to the parentage of the bean, there is quite a lot of additional weight added during preparation. There is still much to learn as to how much inheritance is responsible for variations in the thickness and weight of shell. The whole problem, in fact, of shell on cocoa beans still awaits full investigation.

BEAN SIZE

Both the shell percentage and the fat content of the cotyledons are influenced by the size of the bean. Generally, when the prepared bean weighs over 1 gram, the difference in these characters is small, but when the size falls below 1 gram the increase in shell content and the fall in fat percentage can be considerable. With West African cocoa it has been found that where the size of the bean is over 1 gram the shell percentage remains

constant within 1 per cent. Where, however, the weight of the bean falls below 1 gram, not only is there a greater variation, but the average rise in shell percentage is up to 3 per cent. This means that in West African beans there is a difference between 11 and 14 per cent in shell percentage, by no means an inconsiderable figure. A further point in shell content is that the variation in shell percentage is far greater in small beans than in large ones. Very small and shrivelled beans which should have been eliminated have been ignored in the above assessment.

The effect of size on the fat content of the nib has been determined. Here, as with shell, it is found that the beans with a weight of over 1 gram vary little amongst themselves, whilst those which weigh less than 1 gram vary considerably. The average fat percentage of the smaller beans is in the order of 3 per cent less than that of the heavier beans.

There is, therefore, a definite preference for heavier beans since high fat content is a most desirable quality in a cocoa bean.

ABSORPTION OF EXTRANEOUS FLAVOURS

Prepared beans readily absorb foreign odours and those which are fat soluble are tenaciously held. Proper storage is important. The most common defect from this cause is the absorption of smoke either from drying stoves or from living rooms where open fires of wood are used. This defect is known as 'hammy' or 'smoky' cocoa.

Drying stoves are now seldom the cause of this trouble, damage from smoke during artificial drying is well recognized and precautions against smoke leaks are generally taken. This can easily be controlled because artificial drying is generally in the hands of large producers. The risk of odours being picked up by the storing of bags of finished cocoa in the living quarters of small producers is still present. There is need for special emphasis in wet areas of the world that finished cocoa should be sold as quickly as possible so that it can be stored under properly controlled conditions. Cocoa once contaminated with smoke is ruined for edible purposes. Butter can be extracted from it but expensive refining and deodorizing must be resorted to in order to make an edible product.

CONCLUSIONS

The manufacture of cocoa and chocolate requires a cocoa bean which has:

(*i*) A brown colour and produces a good, clean, strong chocolate flavour on roasting; in other words, has been well prepared.

(*ii*) The lightest shell percentage compatible with protecting cotyledons from breakage; this, as suggested, should be 10 per cent.

(*iii*) A high fat content in the cotyledon. Here it is suggested that 60 per cent should be the minimum aimed at by the plant breeder.

There is no need to emphasize that constancy in these factors is a most desirable quality.

On the negative side, the manufacturer asks that the beans he purchases are free from:

(*i*) Mouldy beans;
(*ii*) unfermented or slaty beans;
(*iii*) inadequately prepared beans with their varying colours and flavours. Purple beans;
(*iv*) beans which have picked up foreign flavours, especially 'smoky' or 'hammy' ones;
(*v*) germinated beans;
(*vi*) broken or damaged beans, which together with (*v*) should eliminate insect attack;
(*vii*) shrivelled or flat beans.

The deleterious effects of these on the manufacturer's products and the problems of production have been discussed in the paper.

(*Received October 1954*)

Statistical Techniques for Inspection Sampling

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The merits of sampling techniques in many problems of inspection are indisputable. In many instances inspection of every outgoing unit is quite impracticable, as, for example, in the inspection of bags of seed for impurities when the sampling units are individual seeds; in these cases the use of efficient sampling procedures can lead to considerable economies. To employ sampling methods to best advantage it is necessary to take account of the theoretical advances which have been made in recent years, and to illustrate this I shall discuss the basic problem of deciding how many units to sample in order to obtain adequate protection against passing a bad patch of produce with, at the same time, the maximum economy of effort and cost.

SPECIFYING THE PERFORMANCE OF THE SAMPLING SCHEME

As a particular case I shall discuss a sampling scheme for inspecting bags of seed for impurities. The special features of this example are:

(1) The number of units (in this case seeds) in each batch presented for inspection is large.

(2) It is relatively simple to obtain a sample that is properly representative of the whole batch. In the example chosen this can be done by thorough mixing before the sample is drawn, but in more difficult cases proper procedures of randomization will have to be used.

(3) The proportion of ' bad ' units will be fairly small, say less than 10 per cent, in all batches presented for inspection. In many applications, the majority of batches coming forward for inspection will be of acceptable quality with a proportion of ' bad ' units of the order of 1–2 per cent.

Since we do not examine all the seeds in a bag, there is always a possibility of our reaching a wrong decision on the basis of our sample results, and such wrong decisions will be of two kinds:

A. We may wrongly reject as unacceptable a bag which is really of acceptable quality;

B. We may wrongly accept a bag which really should be rejected.

The size of the sample will be determined by the necessity of keeping the frequency of these two kinds of error below an agreed level.

To specify a sampling scheme we can start by laying down our requirements for a ' good ' bag in terms of the percentage of impurities that it contains—let us suppose that we agree to regard as acceptable any bag with 1 per cent, or fewer, impurities. If a succession of bags with exactly 1 per

cent of impurities were offered for inspection, some of them would be wrongly rejected (wrong decision of type A). We may now specify that this must not occur with a frequency of more than, say, one bag in 20 on the average.

We should like to reject all bags with more than 1 per cent impurities, but this is clearly not possible; since we are to accept nearly all bags with 1 per cent impurities, we shall, in fact, accept a large proportion of bags whose proportion of impurities is only very slightly greater than 1 per cent. However, we can again lay down a standard level of impurity, say 5 per cent, and insist that bags with this level of impurity shall be rejected by our scheme at least 19 times out of 20 on the average.

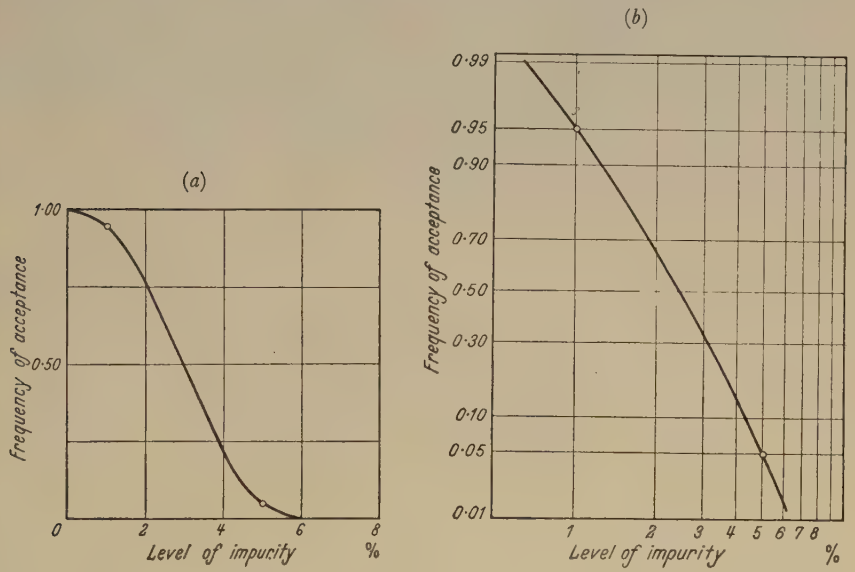

Figure 1 (a) and (b). Operating characteristic of an inspection scheme that meets the specifications

We can now summarize our specification in a table as follows:

Level of impurity (per cent)	*Frequency of acceptance*	*Frequency of rejection*
1	0·95	0·05
5	0·05	0·95

This table can be thought of as giving two points on a complete curve known as the ' operating characteristic ' of the sampling scheme; this curve tells the frequency with which bags of any given level of impurity will be accepted by the scheme. Two features of the curve will be common to all reasonable sampling schemes; a bag with no impurities will always be accepted, and a bag with a large percentage of impurities will always be rejected. An operating characteristic that meets the specification we have laid down is shown in *Figure 1(a)*. *Figure 1(b)* shows the same curve plotted on logarithmic probability paper, when it approximates to a straight line over much of its range.

THE DESIGN OF A SAMPLING SCHEME TO MEET THE SPECIFICATIONS

The next stage is to design a sampling scheme with a suitable operating characteristic, and here there are three main possibilities:

(1) We may take a single sample and base our decision on the result (*single sampling*);

(2) We may take a rather smaller sample and be prepared if necessary to postpone our decision until we have inspected a second sample (*double sampling*);

(3) We may be prepared to take a whole series of small samples, or even to inspect one unit at a time, stopping whenever the result is sufficiently clear-cut (*sequential sampling*).

Of the three methods of sampling, (1) tends to require more units to be inspected than (2), and (2) more than (3), but the choice between them often depends on other factors. Sequential sampling reaches a decision with the least possible labour of inspection on the average, but the actual number of units to be inspected may vary widely from one batch to the next and this may be very inconvenient; it is in any case ruled out if the units cannot easily be inspected one at a time or at least in small lots.

Single Sampling Schemes

In single sampling, we draw a sample of n units, and accept the batch if and only if we find c or fewer impurities in it. By a proper choice of n and c we can arrange that the scheme shall comply with our agreed specification.

Under the conditions we have laid down we can make our choice with the help of a table of χ^2, such as that given by FISHER and YATES (1953) ' Statistical Tables ', 4th Edn. We wish to accept 95 per cent of samples from batches containing 1 per cent of impurities. If these are samples of n seeds, the expected number of impurities will be $0{\cdot}01n$, and the actual numbers of impurities found will follow closely the Poisson distribution. If our ' acceptance number ' is c, we specify that the probability of an observation of c or less in a Poisson distribution with mean $0{\cdot}01n$ shall be 0·95. The relation between the Poisson and the χ^2 distributions is such that this is equivalent to specifying that $0{\cdot}01n$ shall be equal to half the 95 per cent value of χ^2 with $2(c+1)$ degrees of freedom. From the other part of our specification we find that $0{\cdot}05n$ must be equal to half the 5 per cent value of χ^2 with $2(c+1)$ degrees of freedom. We thus require to find the even number of degrees of freedom such that the 5 per cent and 95 per cent values of χ^2 are in the ratio 5 : 1. From the χ^2 table, we find

d.f.	95 *per cent value*	5 *per cent value*	*ratio*
6	1·635	12·592	7·69
8	2·733	15·507	5·68
10	3·940	18·307	4·65
12	5·226	21·026	4·02

so that 10 d.f. gives us the nearest approach to what we require. This implies that $2(c+1)=10$ so that $c=4$, and $0{\cdot}01n=\frac{1}{2}\times 3{\cdot}940$ so that $n=197$. We must take a sample of 197 seeds and accept the batch only if we find four or fewer impurities in the sample.

Owing to the fact that c must be a whole number, this scheme will not meet the specification exactly. We have, in fact, insured that 95 per cent of batches containing 1 per cent impurities will be accepted, but the impurity level at which only 5 per cent of batches will be accepted is given by dividing half the 5 per cent χ^2 value by n, which gives us 4·65 per cent. The frequency of acceptance of batches with 5 per cent impurities will be lower than specified, so that we have got slightly greater protection against bad batches than we have laid down. Using other values of χ^2 with 10 d.f. we can plot the whole course of the operating characteristic, and this is shown in *Figure 2.*

If, as in our example, the units in the sample are inspected one at a time, we need not examine the whole sample—we can reject the batch as soon as five impurities have been found. Under these circumstances the average amount of inspection will be smaller for batches with a high impurity level. When the batch is fairly certain to be rejected the average sample size is given by c/p, where p is the proportion of impurities.

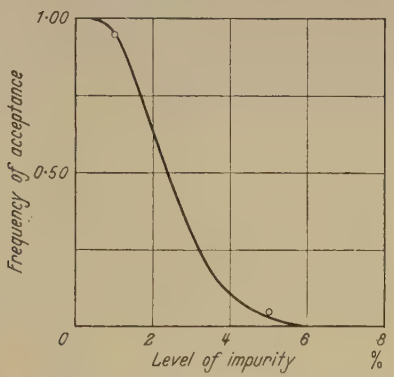

Figure 2. Operating characteristic of a single sampling scheme

Double Sampling Schemes

In double sampling, we first examine a preliminary sample and find the number of impurities in it. If this number is less than a certain limit c_1 we accept the batch, and if it is greater than a higher limit c_2 we reject the batch, but if the number of impurities lies between these two limits we take a second sample and accept or reject according as the *total* number of impurities found is greater or less than a limit c_3. We now have two sample sizes and three limit values to determine which gives us a good deal of flexibility in the choice of a scheme, but investigation has shown that it is usually reasonable to take the second sample to be twice the size of the first, and this restricts the problem to some extent.

In choosing a double sampling scheme, it is convenient to use a slightly different way of describing the operating characteristic. Instead of laying down two points near the tails of the curve, we specify p_0, the impurity level of batches which are as likely to be rejected as accepted, and a quantity h_0 which measures the steepness of the curve at the point corresponding to p_0. h_0, the ' relative slope ', is given mathematically by $-\frac{p}{P}\frac{dP}{dp}$, where P is

the probability of acceptance and p the impurity level. If we have calculated the constants n and c of a suitable single sampling plan it is easy to find p_0 and h_0 from the relations

$$p_0=(c_0+0{\cdot}67)/n_0$$
$$h_0{}^2=(c_0+0{\cdot}73)/1{\cdot}57.$$

In our example we find

$$p_0=4{\cdot}67/197=0{\cdot}0237$$
$$h_0=\sqrt{(4{\cdot}73/1{\cdot}57)}=1{\cdot}74.$$

A selection of double sampling schemes is given in *Table 1**. These should prove adequate for ordinary needs, although a more extensive table could be prepared. The nearest scheme to our requirements is that with $h_0=1{\cdot}72$, for which we find $n_1p_0=2{\cdot}19$, $c_1=1$, $c_2=4$, $c_3=5$. Since $p_0=0{\cdot}0237$ we get $n_1=92$, and our double sampling rule is:

Take a sample of 92 seeds and examine it for impurities. If there are not more than one, accept the batch; if there are more than four reject the batch. If the number of impurities lies between two and four, take a further sample of 184 seeds; reject the batch if, and only if, there are more than five impurities in the combined sample.

The operating characteristic of this scheme will coincide very closely with that of the single sampling scheme having the same values of p_0 and h_0.

Table 1. Operating Characteristics of some Double Sampling Schemes with $n_2=2n_1$

c_1	c_2	c_3	h_0	n_1p_0
1	4	5	1·72	2·19
1	4	6	1·88	2·43
0	4	6	2·03	2·26
2	6	10	2·42	3·77
3	7	12	2·55	4·57
3	8	14	2·88	5·10
3	9	16	3·15	5·68
4	10	18	3·24	6·43
5	10	20	3·33	7·17
4	10	20	3·50	6·99
5	12	24	4·0	8·3

The average sample size of a double sampling scheme will depend on the impurity level and can be obtained by evaluating the probability of having to proceed to a second sample. In our example the second sample is only used if the first gives two, three or four impurities, and the probability of this can be evaluated from χ^2 tables—either tables of significance points as given in Fisher and Yates' tables, or more conveniently, from the actual distribution function as tabulated by Pearson and Hartley (1954) 'Biometrika Tables for Statisticians'. We have to find the probability of getting c_2 or fewer impurities in a sample of size n_1 when the proportion of impurities in the batch is given some value p. This probability is the same as that of getting χ^2 with $2(c_2+1)$ d.f. greater than $2n_1p$. From this we subtract the probability of getting c_1 or fewer impurities, which is given by the probability of getting χ^2 with $2(c_1+1)$ d.f. greater than $2n_1p$. If the resulting

* I am indebted to A. Whitwell for computing this table.

difference is δ, the average sample size is $n_1+\delta n_2=n_1(1+2\delta)$ in our example.

Taking $c_1=1$, $c_2=4$, $n_1=92$ we get the following values:

p (per cent)	0	1	2	3	4	5	6
χ^2	0	1·84	3·68	5·52	7·36	9·20	11·04
$P(\chi^2)$—12 d.f.	1·00	1·00	0·96	0·85	0·69	0·51	0·36
4 d.f.	1·00	0·76	0·45	0·24	0·12	0·06	0·03
δ	0·00	0·24	0·51	0·61	0·57	0·45	0·33
Average sampling size	92	136	186	204	197	175	153

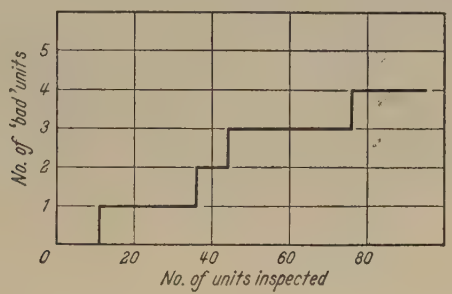

Figure 3. Inspection diagram

Sequential Sampling Schemes

If, as in our example, it is easy to inspect the sample units one at a time, we can take full advantage of the fact by using a sequential sampling scheme. We are now prepared after inspecting each unit either to accept or reject the batch or else to inspect a further unit. We can lay down a rule which will give us a suitable operating characteristic.

Suppose we plot the results of our inspection on a diagram such as that shown in *Figure 3*. We start at 0 and move one step to the right for each

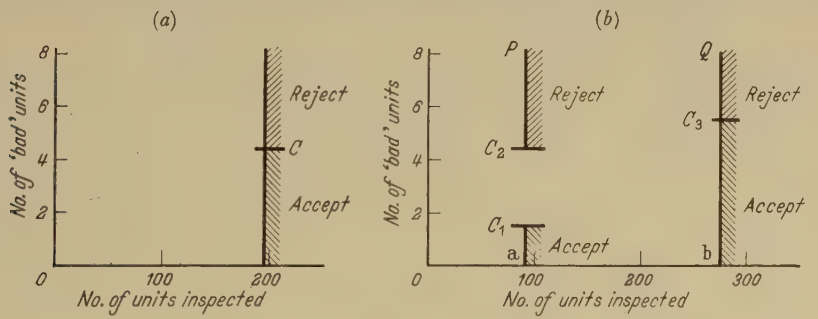

Figure 4(a) and (b). Inspection diagrams with boundaries for single and double sampling schemes

unit inspected and in addition one step up for every 'bad' unit found. On a diagram of this kind a single sampling scheme may be represented by a vertical boundary (*Figure 4(a)*); we continue until the sample line meets the boundary, and then accept or reject the batch according as the point of meeting is above or below the point C. With double sampling (*Figure 4(b)*) we have a second boundary with a hole in it. The batch is accepted if the

sample line meets the boundaries on AC_1 or BC_3, and is rejected if it meets them in C_2P or C_3Q. If the units in the sample can easily be inspected one at a time, we can *contract* both sets of boundary to allow for the fact that the sample line cannot take a step downwards. The contracted diagrams corresponding to *Figure 4*(*a*) and 4(*b*) are shown in *Figure 5*(*a*) and (*b*).

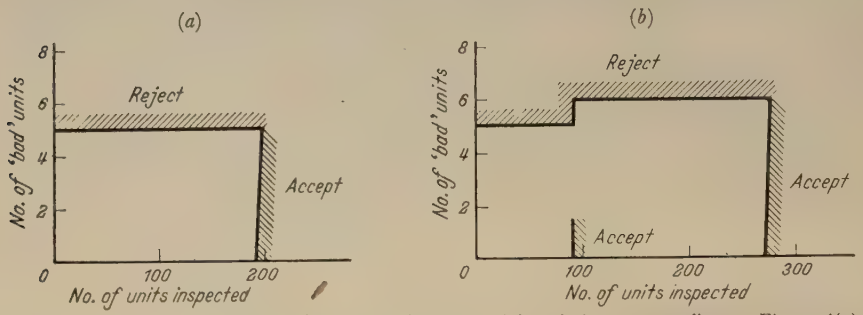

Figure 5 (*a*) *and* (*b*). *Inspection diagrams with contracted boundaries corresponding to Figure 4*(*a*) *and* (*b*)

In a sequential sampling scheme the boundaries are placed as shown in *Figure 6*. If the sample line crosses the upper boundary first we reject the batch; if it crosses the lower boundary first we accept the batch.

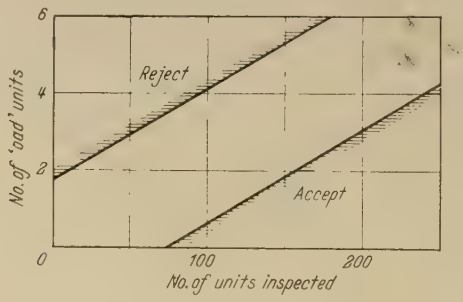

Figure 6. Inspection diagram with boundaries for a sequential sampling scheme

The positions of the boundaries necessary to obtain a specified operating characteristic are very readily found with the aid of the constants p_0 and h_0 introduced in the previous section. If we write n for the number of units sampled and d for the number of ' bad ' units, the boundaries can be plotted on the diagram from the equations

$$d = np_0 \pm h_0$$

Figure 6 shows the boundaries appropriate to our example, with $h_0 = 1{\cdot}74$ and $p_0 = 0{\cdot}0237$. The upper boundary passes through the points $n=0$, $d=1{\cdot}74$ and $n=100$, $d=4{\cdot}11$, and the lower through the points $n=0$, $d=-1{\cdot}74$ and $n=100$, $d=0{\cdot}63$.

There are several ways of using a sequential scheme in practice. One way is simply to use the diagram described above (of which several copies can be provided for the inspectors' use) and actually to plot the results of each sample. An equivalent procedure is to keep a score. We start the score at 0, add 1 for each ' good ' unit and subtract $(\frac{1}{p_0} - 1)$ for each ' bad '

unit. We then accept the batch if the score reaches h_0/p_0 and reject the batch if the score reaches $-h_0/p_0$. In our example, the 'handicap' which is subtracted for each 'bad' unit is $\frac{1}{0{\cdot}0237} - 1 = 41$ and the limiting values of the score are $\pm 1{\cdot}74/0{\cdot}0237 = \pm 74$. If preferred, we can avoid negative values by starting the score at 74 and taking the limits at 0 and 148.

If h_0 is an integer we can express the stopping rule in another simple form. We draw successive samples of $1/p_0$ units and use the following rule:

Accept the batch if we find	Reject the batch if we find
0 'bad' units in h_0 samples	h_0+1 'bad' units in 1 sample
1 ,, ,, ,, h_0+1 ,,	h_0+2 ,, ,, ,, 2 samples
2 ,, ,, ,, h_0+2 ,,	h_0+3 ,, ,, ,, 3 ,,
etc	*etc*

If h_0 is equal to half an (odd) integer we can use a similar rule with an initial sample of size $1/2p_0$.

The size of sample necessary to reach a decision will clearly depend on the actual results of the sampling, the average size being a function of the impurity level. If this is p, and if the corresponding probability of acceptance is P (as read from the operating characteristic), the average sample size is given by

$$\bar{n} = h_0 \, (1-p_0) \frac{1-2P}{p-p_0}$$

The operating characteristic will be very close to that for the single sampling scheme with the same values of h_0 and p_0—the construction of this curve has been described above. Alternatively, we can construct the curve directly from the values of h_0 and p_0. For a given value of P (the probability of acceptance) we calculate y from the relation

$$h_0 y = \log_e \left(\frac{P}{1-P}\right) = 2{\cdot}3026 \log_{10} \left(\frac{P}{1-P}\right)$$

and hence find the value of p (the impurity level) from

$$p = \frac{p_0 y}{e^y - 1}$$

The average sample number curve of our scheme is shown in *Figure 7*. It will be seen that the average sample number reaches a maximum in the neighbourhood of p_0.

The relations given above provide us with a means of obtaining h_0 and p_0 direct from the specification. We specify that the probability of acceptance shall be P_1 or P_2 when the impurity level is p_1 or p_2 respectively, and a little algebra shows that we then must have

$$h_0 = \log \frac{P_1}{P_2} / \log \frac{p_1}{p_2}$$

We can then find $y_1 = \frac{1}{h_0} \log_e \left(\frac{P_1}{1-P_1}\right)$ and hence $p_0 = p_1 \frac{e^{y_1}-1}{y_1}$

The choice of a specification

So far, little has been said about the choice of the impurity levels and the corresponding probabilities of acceptance in our specification. This is, of course, not a purely statistical problem at all, but one of economics. The values chosen will depend, among other things, upon:

(1) The cost of rejecting a batch of any given quality; this will presumably be positive for good batches and negative for bad batches.
(2) The relative frequency with which batches of different levels of quality are offered for inspection.
(3) The cost of the inspection itself.

If these are all known precisely, it is theoretically possible to choose a sampling scheme which is best from an economic point of view, in that the losses due to wrong decisions are minimized relative to the costs of inspection. In practice, however, knowledge of (1) is usually rather sketchy, and of (2) almost non-existent. We are thus thrown back upon common sense, or to be more honest, guesswork.

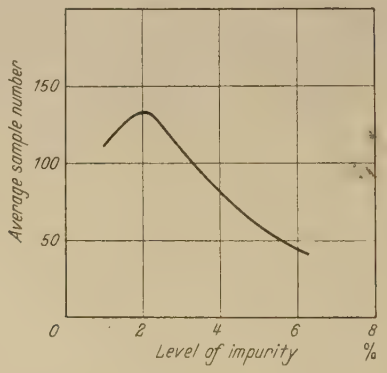

Figure 7. Average sample number curve for a sequential sampling scheme

It is usually bad for morale if a large proportion of batches are rejected, so the upper quality level, at which most batches will be accepted, should be set fairly high. An exception to this occurs when inspection is instituted with the definite purpose of improving quality, when this upper level will correspond to the level the inspecting organization is arriving at. At the other end of the operating characteristic the requirements may be relaxed to some extent. This will be so if most batches offered for inspection are of fairly high quality. If, in our example, only 10 per cent of all batches coming forward have an impurity level as great as 5 per cent we shall reject 95 per cent of these, and of the accepted batches only one in 200 will have this level of impurity.

The choice of the type of scheme—single, double, or sequential—depends very much on the physical nature of the inspection process. Sequential sampling will usually give the smallest average sample size, but samples well in excess of this average will often be required and the provision of these extra units may be costly and inconvenient. A sequential rule is also harder for unskilled staff to follow.

These recommendations are necessarily vague and fragmentary. It is hoped nevertheless that, from the description of various alternative methods of sampling, the potential user will be able to choose the one which best meets his needs.

THE USE OF QUALITY CONTROL METHODS

It should be clearly realized that the sampling schemes here described treat each batch in isolation. If the source of the batch is known we can view it in relation to the results of inspecting previous batches from this source. Often the quality of production at a given source varies relatively slowly and it may be extremely illuminating to plot the results of successive batches against a time scale. This type of procedure, under the name of ' quality control ', has been found very effective in the industrial field. By inspecting the plot we may be able to see that the quality of one producer's output is usually high, with only occasional falls from virtue, while that of another is tending to decline so that a timely warning may save the eventual rejection of a high proportion of batches. Considerable economies can sometimes be made by adopting different inspection schemes for different producers, or classes of producers, according to the usual quality of their output. An interesting example of quality control methods in inspection has been given by Desmond (1954) *Applied Statistics* **3**, 65–73.

(*Received September 1954*)

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Agricultural Extension in Action: The Story of 'AIA'

From the American International Association for Economic and Social Development, New York, U.S.A.

PARTNERSHIP FOR A BETTER LIFE

Thousands of Latin Americans in the year 1954 are learning to be better farmers, better homemakers and better citizens with the help of a co-operative programme of technical assistance being carried out by the American International Association for Economic and Social Development.

A colourful and nutritious meal served in a Venezuelan home, the doubling of milk production on a farm in Brazil, a new sense of well-being gained by rural families in both countries—these suggest the range of benefits being reaped in the sixth year of AIA. Founded by Nelson A. Rockefeller, and financed by him, his brothers and others interested in the development of human as well as natural resources, AIA is actively dedicated to the principle of helping people to help themselves.

The idea of the AIA programme began to take shape in 1946 after Mr. Rockefeller had served in war-time as Co-ordinator of Inter-American Affairs and as Assistant Secretary of State. These assignments brought home to him the need of the so-called ' underdeveloped ' peoples for modern educational and technical tools in creating a better life. It was apparent during the urgency of war-time, as it is today, that no nation can feel either secure or justified in its existence as long as its neighbours are shackled by poverty, disease and malnutrition.

Mr. Rockefeller saw that private citizens, in addition to government, could make an important contribution toward providing the tools for an attack on these age-old problems. So AIA was formed as a non-profit organization to share in this neighbourly enterprise. Since 1946 it has taken to Latin America almost $5,000,000 worth of modern technical knowledge.

AIA's first projects have been in Venezuela and Brazil, where governments as well as private organizations have become active partners with AIA in technical cooperation. In Venezuela, for example, five oil companies interested in supporting philanthropic projects for general development of the country—Creole Petroleum Corporation, Compania Shell de Venezuela, Ltd., Mene Grande Oil Company, International Petroleum Company, Ltd., and Socony-Vacuum Oil Company of Venezuela—have contributed the bulk of AIA funds used in Venezuela. The original AIA funds were matched by the Venezuelan government for the first three-year contract in 1948. Since 1951 the government has been making a two to one contribution toward support of AIA's projects in that country.

In Minas Gerais, Brazil, where AIA is guiding a state-wide rural rehabilitation programme, the state government has assumed an even greater responsibility for financing.

In its early years, AIA had to search out techniques which would best serve the job of development. Up to the present, it has worked principally with individual farmers, their wives and children—showing them how to eat better at no extra cost, boost crop yields, make home improvements, feed their cattle in the dry season, and combat erosion. The common technique has been the simple, practical demonstration.

Today, at the request of official agencies in both Brazil and Venezuela, AIA is shifting its emphasis from direct demonstration to training others for the same job. The new phase is designed to add to the core of professionals—extension agents, home economists, and specialists of various kinds—who can expand and bring to more people the programmes which AIA has initiated. It not only broadens AIA's area of influence, but also moves closer to its ultimate goal—of leaving the operating programmes in the hands of governmental agencies alone. Only in this way can their continuity be assured and the new techniques woven into the fabric of national life.

As the American International Association starts its seventh year of working with people, it reaffirms the purpose which has guided its job of technical assistance. For this purpose it has taken ideas from many sources, combined them, adapted some, discarded others and tried new ones. It has come out with workable, if not perfect, formulas for helping people to help themselves—for the ultimate good of everyone.

IN VENEZUELA

Tools for Economic Development

Supervised Credit and Extension Techniques—To assist agricultural development in Venezuela, AIA has been conducting a programme of supervised credit for the small farmer. In six regions of the country, from the rugged Andean hills to the grassy, rolling *llanos*, supervised credit has proved one of the surest ways to promote economic growth under all types of farming conditions.

Administration of this programme, started in 1948, is in the hands of an autonomous *consejo*, or council, on which officials of the Venezuelan government sit with an equal number of AIA representatives. The board is known as the Consejo de Bienestar Rural (CBR); in English, the Rural Welfare Council.

CBR's major activity to date, the credit programme, is patterned after techniques first employed by the Farm Security Administration, which proved so successful in the United States. Distinct from high-cost commercial credit, supervised credit makes modest funds, along with expert agricultural know-how, available to reliable small farmers. At a farmer's request the local CBR agent, who is a trained agronomist, surveys the needs of both his farm and home. Working together they develop a loan plan, modest enough to be within the farmer's limited means for repayment, yet ambitious enough to make real improvement in his farm income and living conditions. The plan specifies the use of the loan in detail—perhaps the purchase of a plough, a small plot of adjacent farmland, improved seed varieties, or concrete flooring for the house. It is then presented to the loan agency, the Banco Agricola y Pecuario, for approval.

The CBR expert's real work with the farmer begins after the funds are granted. Once a month or more, he comes around to give advice and assistance on the myriad problems of farm management. The farmer learns to kill leaf-eating ants with chlordane, to conserve the soil by planting his hillside crops on contour, to irrigate for better yield, and how to use fertilizers. Beyond the economic implications of these new practices, the farmer soon develops a sense of pride in his progress toward the goals of the loan plan. He may take a special pleasure in making a repayment in advance of the due date. Most of all, he profits by the friendly contact, perhaps his first one, with someone who takes a genuine interest in helping him solve his problems.

The soundness of CBR's farm loans is attested by the figures. By the end of 1953, 1,121 loans totalling $1,138,770 had been made, with only 4 per cent in default. Net yearly income of borrowers had risen over 300 per cent, from an average of $362 to $1,133. While the actual number of loans has been small, they have proved the point that supervised credit, until recently unknown in Venezuela, is one of the most effective instruments for raising farm output and living standards in rural areas.

CBR technicians bring information on up-to-date farm practices to a much larger group than the borrowers alone. Last year more than 10,000 farm families in Venezuela took advantage of educational activities conducted by the CBR extension service. At some meetings they saw films or listened to a talk, and received pamphlets on such subjects as insect and weed control and home sanitation. In a number of communities groups of farmers witnessed tests on demonstration farm plots showing sample yields with and without benefit of fertilizers and improved cultivation practices.

CBR agronomists have given helpful advice to many more who called on them individually; many a jeep carrying a technician to a scheduled meeting is stopped along the way for unscheduled, but frequent consultation.

Home Management—Complementing its credit and technical assistance work with the farmer, CBR has been introducing to his wife new techniques of homemaking. She is learning how to provide better diet for her family by cultivating a small home garden, planting new varieties of fruit and vegetables and preserving food for year-round consumption. She is taught that better health can be achieved by the use of privies, wearing shoes and drinking pure water, and she learns how to provide more comfort in the home, generally, with the addition of decorative, functional furniture. All of these improvements, which are taught by demonstration methods, have been reduced to easy and economical procedures.

Like the farm technicians, CBR home economists make individual visits to both borrowing and non-borrowing families. In addition, more than a dozen community centres, located in CBR credit and farm extension areas, have been providing group instruction for women in sewing, cooking, canning and light carpentry. At some of the centres, a children's breakfast programme has been developed to give pre-school youngsters much-needed extra nourishment, to teach basic habits of hygiene and provide wholesome recreation.

Technical Training—The training of farm youth in the operation and maintenance of agricultural machinery has been an important adjunct to

Figure 1. A ' graduation day ' parade of tractors at a CBR training centre

the CBR programme. At a training centre in the state of Yaracuy, hundreds of young Venezuelans, many of whom had never even ridden in a car, have learned to manoeuvre heavy tractors and use their various attachments for planting, dusting, discing, harrowing and fertilizing. They have also received instruction in good farm practices.

A recent survey shows that many of the trainees, who number over 600, have obtained better jobs paying higher salaries than they could otherwise have expected. Those who are farming for themselves are setting their neighbours an example, practising better methods of cultivation and making substantial home improvements. While not an extensive programme, the training in farm mechanization has served as an opening wedge in getting new technical knowledge to rural areas.

In accordance with its new emphasis on teacher training, CBR has turned over most of its present field operations in credit, extension, home management and farm machinery training to various agencies of the federal and state governments. One area will be retained as a demonstration centre. Here will be focused a new CBR programme, getting into motion this year, for the in-service training of government personnel—farm agents and home economists—employed by the Agriculture Ministry and National Agrarian Institute.

Special Studies—CBR is contributing an entirely different form of technical assistance in Venezuela through a series of studies on production bottlenecks in agriculture. The latest is an economic and social survey of Venezuela's three Andean states, one of the country's most populous regions. From this comprehensive study, the first in Venezuela to utilize experts from many different professions, the government will find leads for developing the economic potential of the area.

Scholarships—For the past six years, AIA has been co-operating with the Inter-American Institute of Agricultural Sciences to provide scholarships for young Venezuelans to study at the Institute in Costa Rica. The programme

Figure 2. ACAR's campaign to improve cattle through use of silage in the dry season has brought quick increases in income for dairy farmers

is intended to equip farm youth for more complex tasks in agriculture and thus contribute to essential economic development.

Since 1948, 80 young men have taken one or two years of such training. Now they are working for agencies of the government, on private farms, and as CBR agronomists. One has a job with a bank—specializing in agriculture. Recently the programme has been revised to take candidates at a higher educational level so that graduate degrees can be earned either at the Inter-American Institute or at Cornell University.

Teacher Training for Trade Schools—AIA is entering a new field of activity this year in Venezuela. To help fill the need of a developing nation for skilled labour, AIA will conduct a two-year programme of teacher training in co-operation with the Ministry of Education. The programme is designed to furnish teachers for the country's ten industrial and trade schools who are both professionally skilled and good instructors.

AIA is developing a national training centre at Valencia where some 120 prospective teachers, as well as a permanent teaching staff for the centre, will be given courses based on shop instruction methods employed for ' manual training ' in U.S. high schools.

Nutrition Education: New Attack on an Old Problem

The heavy toll taken of large numbers of the population in deaths and illnesses caused by malnutrition has long been a matter of concern in

Venezuela. In 1948 officials of the country decided to co-operate with AIA in launching a new attack on the problem—a mass information programme.

To tell the story of better nutrition, another council was set up with joint AIA and Venezuelan representation. CIDEA, for Consejo Informativo de Educacion Alimenticia, or Information Council on Nutrition Education, became the first education programme in Venezuela to use nation-wide media of communication.

Newspapers, magazines and radio stations readily agreed to open their columns and airwaves to CIDEA's free services to bring the message of better living. Today, with additional media of special publications, TV and motion picture programmes, and club organizations, to name a few, CIDEA is reaching upwards of 1,500,000 persons every month—one out of every four Venezuelans.

CIDEA gives children special attention because of the long-range consequences of diet and the need to form good habits early. They are reached in the schools through regular nutrition courses which CIDEA helps to organize by giving guidance to the teachers and providing instruction manuals. CIDEA also encourages children to form extra-curricular nutrition clubs. Four-colour comics have been adapted for entertainment with a nutrition message. Athletic heroes, such as Chico Carrasquel and Joe DiMaggio, have been enrolled in the campaign to give advice on good diet to boys and girls. In the past 18 months more than 1,300,000 copies of six titles of pamphlets have been distributed throughout Venezuela, principally to children.

Newspapers make frequent use of the CIDEA press service from New York where world-wide news on nutrition, agriculture and public health is sifted and keyed to Venezuelan interest. Fifty-one publications in the more than 20 states and territories regularly reserve columns for CIDEA news. About 150 different feature items, supplied by CIDEA from its Venezuelan and New York services, reach an average of 550,000 readers monthly; 5,000 clippings in 1953 testify to the acceptance of this free service.

CIDEA's radio activities are extensive: 53 stations, in virtually every state, carry its programmes. These include a daily news bulletin, a round-table quiz in which questions are answered by top educators and public health specialists, adventure stories for children, and a weekly dramatic show on history and folklore with nutrition angles. Four TV stations—three in Caracas and one in Maracaibo—have recently developed a significant audience, so CIDEA is also producing a 30 minute live telecast, 'Life Begins at 70', a panel programme featuring reminiscences of oldsters on the foods to which they attribute their longevity.

CIDEA maintains five mobile motion-picture units on the road. From small trucks equipped with generators an average of two showings a day are given in towns and remote villages, of which some have never seen movies before. Usually the driver-operator sets up his equipment in the village squares and projects the films against the wall of a building. He may show two or three shorts on nutrition and health themes with a comic or sports reel thrown in for entertainment. The second member of the mobile unit

team then gives a short talk over the truck's loudspeaker and distributes illustrated pamphlets to leave the message firmly behind. Eighteen sound-trucks of the Ministry of Education have also been made available for showing the four original films which CIDEA has produced, as well as others that have been adapted for use in Venezuela.

How successful has CIDEA been in telling the story of better diet ? Though it is difficult to measure CIDEA's contribution statistically, there are indications of a rising nutritional level in Venezuela. Diseases due to malnutrition have dropped off, according to recent figures of the National Nutrition Institute of the Health Ministry. There has also been a marked increase in the consumption of basic foods to which CIDEA has repeatedly called attention. For example, in 1946 there were only two pasteurized-milk plants in the country. Today there are seven, and the annual *per capita* consumption of milk has increased from 23 to 73 quarts in the same period. A demand for more dairy products, vegetables, fruit and protein foods is, of course, part of the country's normal development, but CIDEA can be credited with quickening this demand.

At the government's request CIDEA is expanding information activities in the field of public health, such as child care, sanitation and preventive medicine, and like CBR, is giving new emphasis to training. Last year CIDEA trained 18 special representatives for assignment to as many states for the purpose of co-ordinating school nutrition work, film showings, adult clubs and other CIDEA-sponsored projects in these areas.

IN BRAZIL

Farm Demonstration Work in Sao Paulo

AIA's first Brazilian programme started in the state of Sao Paulo where a demonstration of spraying to control livestock parasites became the talk of the county in 1948 and created interest in bringing other modern farm practices to Santa Rita do Passa Quatro.

AIA's programme in this rural community—extended later to a nearby municipality, Sao Jose do Rio Pardo—has not followed the usual pattern of co-operative projects with government agencies. Here, the dairy farmers themselves got the programme under way by contributing three days' earnings from annual milk sales into a joint fund with AIA. This private support continues even today, though the state is also a partner in the programme.

Essential elements are a farm extension service, not unlike that provided by U.S. county agents, agricultural clubs for children, home management counselling and a mobile medical service.

A former coffee-rich area, Santa Rita turned largely to dairying after a world price drop in the 30's and increasing debilitation of the soil made coffee growing uneconomical. Improvement of livestock and milk production has been a major aim of AIA in this area. Vaccination, spraying, introduction of low-cost efficient trench silos to provide feed during the winter dry season, and artificial insemination are some of the techniques that have resulted in more milk and more money for the farmer.

AIA is also encouraging him—especially the small, independent farmer who works his own land without benefit of tenant families—to try new

crops and to balance his production for year-round yield. On AIA's recommendation, farmers have gone into citrus production with profitable results and are cultivating new varieties of vegetables to enhance the family dinner-table as well as bring higher prices at market.

AIA agronomists find that introducing a new technique to the community is made easier by starting with children or with the farmer of some education and financial stability. The small farmer, who cannot afford to take what seems like an enormous risk, is best convinced by seeing results.

Participation by children in garden clubs, where they learn proper methods of cultivation under the agronomist's supervision, instills interest in farming as a career besides bringing indirect influence to bear on their parents. AIA's community nursery supplies seedlings for home vegetable plots from which the youthful farmers bring their best specimens for exhibit at the annual county fair. Here they are judged by leading agricultural experts of the state. A popular project is the raising of hybrid maize to which a whole year's club work may be devoted.

AIA helped to initiate mobile medical units, which are sent out by the state's ministry of health. These have proved a boon for isolated farm families. Consisting of a doctor, nurse, dentist, and sometimes the agronomist who goes along to distribute seedlings, each unit visits scheduled outposts twice a month to treat parasitic infections, vaccinate, give medication and inspect teeth. Emphasis is placed on measures for the prevention of disease as well as curing immediate sickness.

The nurse, who is also trained in home management, remains in the afternoon with farm wives after the departure of the mobile unit. She works informally in their homes and kitchens, giving assistance on problems of nutrition, sewing, sanitation and child care.

The example of this type of community-wide service in bettering agriculture, health and living standards, has stimulated the interest of farmers in widening circles. From all over the state and even adjoining states, *fazendeiros* have come spontaneously to look and learn about trench silos, hybrid maize and healthy herds.

Plans are now being worked out for the state of Sao Paulo to assume operating responsibility for the programmes in Santa Rita and Sao Jose so that AIA's chief agronomists will be free to help inaugurate similar activities in new areas.

12,000 Families Point the Way

In Brazil, as in Venezuela, AIA has been co-operating with government to provide farm credit along with extension facilities for rural rehabilitation. Here the operation has so far been confined to one state, Minas Gerais, to the north of Sao Paulo, which is almost as big as Texas and more populous than Venezuela.

In this programme, the state of Minas Gerais is now a four to one contributor with AIA through the autonomous Associacao de Credito e Assistencia Rural (ACAR), or Rural Welfare and Credit Association, set up like the Venezuelan *consejo*, and all but four of its 100-member staff are Brazilian.

Twelve thousand rural families are now served by ACAR. A good example of the very small farmers who have been helped by supervised agricultural credit is shy, industrious Jose Grossi Toledo, an ACAR borrower in the municipality of Uba.

Jose has received four ACAR loans since May, 1950. In that year, his ten-acre farm was so unproductive that he was forced to take more or less regular employment as a bricklayer when he wasn't actually planting or harvesting his small crop. He, his wife, Luzia, and their four children lived in a three-room shack with a dirt floor. There were no other farm buildings. They raised mainly tobacco, the principal crop of the area, as well as a little maize, beans, rice and poultry for home use. Jose still owed part of the purchase price on his property.

When Jose heard about ACAR's programme, which had only been operating in Uba since 1949, and expressed an interest in joining it, his neighbours told him it was some scheme to take his land away. But he went ahead despite their warnings and conscientiously carried out every detail of the programme which the ACAR agronomist developed with him. As a result of hard work, enlightened farm management and credit totalling $2,600, the value of his farm has soared enormously. In 1950, it was estimated at $1,000; recently, Jose turned down an offer of $5,000. After seeing his progress unfold almost miraculously before their eyes, six of the same sceptical neighbours applied, themselves, for ACAR assistance.

One of the first improvements which Jose made under the guidance of the ACAR agronomist has proved one of the most profitable—a small water-powered mill for grinding maizemeal, a basic item in the Brazilian diet. With the expenditure of about $200 of loan funds for materials, he diverted a stream to supply power, built a small concrete structure and installed grinding equipment. In the first year, Jose ground over 42 tons of maize for himself and his neighbours; the mill paid for its cost and netted him a $200 profit. In addition, this investment has contributed greatly to the value of the farm.

Another basic and far-reaching improvement which Jose made in accordance with his ACAR programme was the purchase for $60 of half an acre of apparently useless, over-grown swamp, adjacent to his property. Jose cleared and drained the land, provided irrigation canals and then planted rice. That year, the crop paid for the price of the land and supplied all the rice Jose needed at home. This year he is growing onions, in the next season another crop of rice and so on in rotation for years to come because the land is fertile and well suited to intensive culture.

Also, part of Jose's farm plan was the renting of an additional seven-and-a-half acres for growing more tobacco, which pays well at present prices. With his loan funds he bought a scale to weigh crops, put up a drying shed and a temporary storage barn, all modest improvements, but in keeping with the means of a small farmer.

Before planning his farm economy with ACAR, Jose could not afford to employ any extra labour. Now he has the help of another family who live in a small house on the farm. He has progressed also through the use of better seed varieties, such as hybrid maize. It was difficult at first for the agronomist to get him to plant the hybrid and he had to make him a present

of an eleven-pound bag of seed. The maize made such a showing that the following year Jose bought five times as much on his own initiative.

The big structural addition on the farm is a new house. Life is more pleasant these days for Jose and Luzia. They have more rooms, electricity, a hardwood floor, and enjoy looking out over their farm from an elevated site. Because of its incline, the bare hillside sloping down in front of the house needed protection from erosion and to control the fine dust lifted by every passing breeze. For this purpose, the agronomist worked out with Jose a plan for terracing the slope with orange and avocado trees. These will also provide shade and a new source of vitamins. They have built a privy and protected their fresh-water supply from pollution.

Near the house, Luzia has started a small vegetable garden with the encouragement of the ACAR home supervisor, feminine counterpart of the ACAR agronomist, who accompanies him on his daily rounds. Luzia is now treating Jose and her growing family to many nutritious fresh greens and other vegetables which they previously did not raise and could not afford to buy. They are sleeping on comfortable, maize husk mattresses and have porch benches and house furniture which Luzia learned to make with a group of neighbouring women who meet regularly for instruction with the home supervisor. Of the 28 class members, only three are wives of borrowers; ACAR's technical assistance is available to everyone in the area whether they are members of the credit programme or not.

Other non-credit activities in which ACAR personnel are engaged include: organizing 4-H type clubs for children to develop young personalities and skills often neglected in the isolation of farm life; assisting the state health department to bring more medical facilities to isolated rural areas; and helping private companies to develop health and education programmes for their worker families.

Though he has come a long way with the help of ACAR and his own industry, Jose is eager to do even more. In the future, he plans to install running water in the house, build a better storage shed, and lay a cement floor in the pigpen. This is the important contribution that ACAR has made to the lives of small farmers like Jose Toledo—that they are able for the first time to think about tomorrow, instead of spending all their energies in the struggle with today.

Recently, AIA signed an agreement with representatives of the federal Bank of Brazil and the newly-created Northeast Bank to carry the ACAR formula into eight states of Brazil's vast north-east drought region. From its headquarters in Belo Horizonte to its local offices in 40 counties of Minas Gerais, ACAR is serving as a training centre for personnel of the fledgling association—the Associacao Nordestina de Credito e Assistencia Rural (ANCAR), whose name itself is borrowed from ACAR.

ANCAR's technicians will soon be bringing farm and home assistance and supervised credit into an area one-sixth the size of the U.S., and many more families will one day be able to face the future with hope instead of despair.

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Two Pilot Schemes to Solve the Overstocking Problem in Tanganyika

From the Department of Veterinary Services, Tanganyika

INTRODUCTION

The vast majority of the African population of Tanganyika lives at an altitude of over 3,000 feet above sea level between longitudes 30° to 38° E and 1° and 8° S where there is an annual mean rainfall of between 25 in. and 35 in. These conditions make much of the area marginal for agriculture although quite suitable for raising livestock.

The African peoples of Tanganyika can roughly be divided into two categories; the herders of cattle who carry out virtually no cultivation, and the cultivators who have, to varying extents, developed a liking for livestock which they use as a capital account to be drawn on in times of famine and other misfortune. Unfortunately, the livestock are concentrated in relatively small areas of the Territory because of the presence of tsetse fly and the shortage of permanent water supplies. Thus, the occupied land tends to be over-cultivated and/or overstocked.

One of the greatest problems, therefore, is the redistribution of stock to prevent further serious deterioration of the land in the overstocked areas.

The simplest way of tackling this problem would be to compel the owners to dispose of their cattle by redistribution and by sales on livestock markets. There are practical difficulties to this, and other ways must be used; for example, the provision of reliable water supplies and the clearing of tsetse-infested bush in order to make available additional grazing. Stock reduction has been effected in Tanganyika in several areas, of which the most successful to date has been in the Iraqw area of the Mbulu District.

These destocking schemes, however, leave unsolved two major problems in the livestock industry; the first, how to use to the best advantage the large areas of natural grazing which are ideal for large scale ranching purposes but which might be ruined by present-day mismanagement by stockowners, and, secondly, how to absorb and prevent the slaughter of the many immature animals which come on to the markets in the course of destocking programmes. These two problems have been investigated and the Government Pilot Ranching and Immature Holding Schemes on the Mkata Plains suggest a solution.

THE IRAQW CULLING SCHEME

The Iraqw Chiefdom lies in the Mbulu District of Northern Province, and in 1948 the occupied area was approximately 850 square miles; that is, a long narrow strip running north and south, about 85 miles in length and on an average less than 16 miles wide, along the top of the Rift Wall at an altitude of something over 5,000 ft. The tribe was originally confined to a small area—Kainam—in the east-central part of the Chiefdom, but over

the last 150 years they spread progressively to the north, south and west from this cradle area. The occupied area became stabilized in 1948 when the encroachment by tsetse fly was halted by clearing a fly barrier along almost the whole length of the Chiefdom's western border.

When the Iraqw people first spread over their Chiefdom, both they and their livestock benefited from the comparative fertility of the new land and multiplied rapidly, and they abandoned the sound agricultural and animal husbandry practices which they had been forced to adopt in the confined area of Kainam. Very soon signs of over-cultivation and overstocking became apparent throughout the Chiefdom. By 1945, the alarming deterioration of the land evinced that if the ever-increasing human population were to be supported within the Chiefdom's boundaries, some drastic measures would have to be taken.

It was obvious from the start that an important factor was overstocking. A stock census carried out in 1948 disclosed that the assessed carrying capacity of the North Iraqw grazing of six acres per stock unit was exceeded as only 5·4 acres were available per stock unit. In Central and Southern Iraqw where the assessed carrying capacity was 3·5 acres per stock unit, the actual stock density was at the rate of one unit per 1·66 and 2·3 acres respectively. By totals there were 2,377 (10 per cent) surplus stock in North Iraqw; 30,615 (52 per cent) surplus in Central and 42,534 (33 per cent) surplus in South Iraqw. (One stock unit was defined as one adult bovine, two calves, five sheep or goats or one donkey.) It was on record that since 1941 the cattle population had been reduced by 20 per cent, mainly due to death by starvation, and the stock owners themselves were quite prepared to agree that during the last decade the size, quality and milk production of their animals had been reduced.

It was therefore proposed to devise some scheme to reduce the pressure of livestock on the occupied land in order that grazing could be rehabilitated. Redistribution of animals to areas outside the Iraqw Chiefdom was not practical as other tribal areas in the Mbulu District were stocked to capacity. However, certain parts of the Iraqw Chiefdom, particularly in the south-west, were covered by tsetse-infected bush and the occupation of these areas seemed to be the only alternative to selling off all surplus animals on the markets. In short, the plans included the following:

(*a*) North Iraqw: all the 10 per cent surplus livestock to be sold at markets, while 120 square miles of tsetse bush was to be cleared and used for the resettlement of surplus stock from Central Iraqw.

(*b*) Central Iraqw: the eastern portion of this part of the Chiefdom—Kainam—was to be excluded from the destocking scheme as there were no signs of soil deterioration and it did not appear to be overstocked. The rest of the area, however, was to dispose of most of its excess stock, *i.e.* 32 per cent by sale, while some 12,000 more stock units were to be resettled in the new tsetse clearings in North Iraqw.

(*c*) South Iraqw: although there were some 200 square miles of tsetse bush which could be resettled in due course, it was estimated that even selective clearing would take some eight years to accomplish.

> It was therefore proposed that the destocking programme should include the sale of all surplus stock in South Iraqw, but that as this south-west expansion area was cleared it should be resettled and the numbers of animals to be sold on the markets reduced accordingly.

The destocking programme was to be regulated and controlled under authority of a set of Destocking Rules made under the Natural Resources Ordinance.

When drawing up these rules it was important that the peculiarities of the tribe's system of holding cattle should be taken into account, and among these was one important factor—the system of loaning cattle. Apparently about 75 per cent of the total cattle population was owned by some 10 per cent of the people, but most of these animals were loaned out in smaller numbers to friends and relations of the owners, with the result that almost all households possessed some stock, though herds were still small—not normally more than 10 head, and rarely exceeding 20. It was realized that due to the conditions attached to these loans the destocking of herds might lead to some of the loaned cattle being returned to their owners, and this would merely cause a greater concentration of stock in parts of the already overstocked areas, while depriving many people of the milk which formed an important part of their diet. Fortunately there was, however, no religious or other form of attachment to any animal, except to the founder of any particular person's herd.

Propaganda had been going on for some years, but in 1947 efforts were intensified and by 1949 the tribe was suddenly prepared to accept in principle the destocking scheme as outlined above. This sudden favourable decision on the part of the tribe appeared to be due to three main causes; first, the approval of the scheme by the influential ' king-maker ' of the tribe; secondly, the people's increasing confidence in Government and its local officers through the visible tokens of Government's assistance to the people; and thirdly, the realization that the land and stock were deteriorating and that something had to be done about it.

In December 1949 the scheme for destocking the Iraqw Chiefdom, together with the necessary rules, was submitted to Government. Destocking was to continue for a period of three years, by which time it was planned that the numbers of livestock would have been reduced to the carrying capacity of the land, when it would be necessary to institute a quota system to dispose of the annual natural increase of animals so as to maintain the correct balance between livestock and available grazing. It was considered that the northern portion of the Chiefdom could dispose of its 10 per cent surplus livestock in one year, but that the southern areas would require the full period of three years to destock to the required level. As the annual natural increase in this area was calculated to be about 10 per cent for cattle, the annual destocking programme for Central and South Iraqw was fixed at 20 per cent.

The full scheme could not be started until the rules had been agreed by Government, but early in 1950 the people were persuaded to start disposing of their animals on a voluntary basis, and for all stock units sold on the markets destocking tickets were issued. Unfortunately, there was a slump

in prices and it was realized that it would be unfair to stock owners if they were not given some latitude in their choice of market and time of selling. Thus, the people were given six months in which to sell one-half of their assessed annual quota, and any animals which they failed to sell in that period were then branded and sent for compulsory sale at the next available market.

In June 1950 the rules were agreed and published by Government and immediately stock owners in Central Iraqw were assessed and orders issued for the sale of 12 per cent of their stock during the last quarter of that year. In the event $12\frac{1}{2}$ per cent of the stock in that area were sold and no cases of refusal to destock were taken to court. At the beginning of 1951 North and Central Iraqw were given their full quotas for disposal (10 per cent and 20 per cent respectively for the year), whereas South Iraqw was given a quota of only 14 per cent of their stock holdings to dispose of during the year as they had voluntarily disposed of $6\frac{1}{2}$ per cent during the previous year.

After the first full year of destocking two points seemed to be outstanding. The first was that the scheme appeared to be working successfully, and secondly, destocking appeared to be taking the form of a culling programme, as most of the animals coming on to the markets were of a very poor quality. Two loopholes were discovered in the rules. The Kainam area of the Iraqw Chiefdom, and the Barabaig Chiefdom immediately to the south of Iraqw were both exempt from the destocking scheme but stock owners in both areas had been selling their cattle at markets in order to obtain destocking tickets, which they promptly traded to those Iraqw tribesmen who were supposed to destock. At the same time a number of Iraqw tribesmen had moved from the southern part of their Chiefdom into the Barabaig country in order to avoid destocking or stock counts, thus tending to cause overstocking in Barabaig, if the moves were permanent, or upsetting the destocking programme in Iraqw, if the moves were temporary. The illegal trade in destocking tickets was stopped by imposing a low destocking rate in Kainam and refusing to issue destocking tickets to any Barabaig tribesmen who sold cattle on the Iraqw markets. It was virtually impossible to prevent the movement of Iraqw livestock into Barabaig, but a system of recording the movements was begun and pressure was brought to bear on the Barabaig to return any Iraqw livestock back to their own Chiefdom. At the same time a survey was begun of the Barabaig Chiefdom to assess its stock-carrying capacity in the hope that it would be found possible to find room for some permanent Iraqw settlers.

During this year also, settlement was started in the northern expansion areas into which settlers were allowed to move together with not more than eight stock units per household. Clearing had also taken place in the western expansion area and so many people had moved in with their stock that destocking had to be considered there. By the end of 1952 stock numbers had been stabilized in the northern portion of the Chiefdom, while in the south numbers had been reduced below those permissible, though in part this was due to movement into the Barabaig Chiefdom. During that year also some 130 square miles and 380 square miles of bush clearing had been carried out in North and South Iraqw respectively, and these areas made ready for settlement.

In the previously overstocked areas the relief on the land had been enough to allow the grass to grow sufficiently for fires to start. At the same time an attempt was made to improve these grazings by the eradication of the inedible wire grass (*Pennisetum Schimperi*) by the reservation of square mile blocks of grassland which were then burned off.

During the last year of the destocking scheme—1953—the destocking programme was completed over the whole of the Iraqw Chiefdom, but by this time breeding herds had been reduced to such a level that the tribesmen began to sell large numbers of immature cattle, which created a problem in itself and new markets for this class of stock had to be found.

A new system of area quotas, with the idea of controlling the natural increase, was now put to the Native Authorities, who received it well.

The reasons for the success of this scheme, the first of its kind in Tanganyika, may be said to fall into two categories; first, the full support accorded to it by the 'king-maker', probably the most influential single member of the tribe, and by the Native Authority, and second, the sympathy with which the Government Staff administered the Destocking Rules. For example, every care was taken to avoid individual hardship, and the rates of destocking were reduced if any calamity had visited an individual herd. Similarly, trek oxen, which are used to a large extent in cultivation work in this chiefdom, were exempt from destocking. At the same time, the assistance with bush clearing which Government gave to the tribe, was much appreciated by the tribesmen and spurred them on to greater efforts on their own behalf. There is no doubt, also, that the proportionately greater staff made available to the district and the continuity of service of Government officers within the District (there were only two district commissioners within a period of 10 years) played an important part in making the Scheme a success, especially in its early stages. It is perhaps also fortunate that the Scheme began at a time when livestock prices were consistently rising throughout the Territory.

MKATA PLAINS SCHEMES

As was mentioned above in the introduction to this paper, many parts of Tanganyika Territory are suitable for livestock and it was thought that large-scale ranching operations might be an economic proposition in some places. In 1949 proposals were made to start a pilot ranching scheme on the Mkata Plains in order to indicate the best methods of ranching practice and gain some insight into the disease factors which might arise.

The Mkata Plains lie at a height of some 1,200 ft. above sea level about 25 miles west of Morogoro, and cover an area of approximately 550 square miles in the flood valleys of the Mkata river and its tributaries. This area has a mean annual rainfall of about 35 in., and much of it, especially the higher land, is covered with tsetse-infested bush. The area chosen for the pilot ranching scheme lies alongside the Central Railway Line, which is not only a means of ready access, but also endangers grazings by fire in the dry season.

The scheme began in the middle of 1949 and by the end of 1950 over 1,000 head of cattle were held. Flooding during the 1949–50 rainy season was not serious and it was never found necessary to move the cattle from the

relatively fly-free lower areas to the higher ground, where the fly danger was greater. By means of regular dipping it was found possible, in spite of the periodic introduction of East Coast fever into the ranch with imported stock, to reduce losses from tick-borne diseases to a very low level.

Unfortunately, to begin with, the only permanent water available for stock was in the rivers which were bordered by fly-infested bush and many cattle became infected with trypanosomiasis, but early treatment with trypanocidal drugs (mainly dimidium bromide) reduced mortality to a very low figure. Later on, however, it was possible to sink bore-holes and water was discovered in two wells at a depth of about 30 ft.

During these two years the rainfall in the catchment areas of the main rivers did not cause serious flooding; water over the inundated land was quite shallow and grass grew readily as the flood receded. Local rains, however, were found to have a much more serious effect on the land as the cattle readily puddled the heavy black cotton soil and at the same time caused very muddy conditions in the kraals. It was therefore found essential that the cattle kraals should be lightly constructed and, above all, movable. However, it was not necessary by the end of 1951 to retreat from the lower flood plains to the higher land.

The danger of fire from the railway was found to be quite serious and it was essential to plough out fire-breaks, which were also used to divide up part of the area into 100 acre blocks. This system of paddocks allowed a rotational grazing scheme to be started.

By the end of 1951 the breeding herd on the ranch was built up to a strength of 161 Boran and 404 local Zebu breeding females which were run with Boran, Sudanese and local Zebu bulls. There were also 216 calves as well as 518 bulls and steers of varying ages which were to be grown out and fattened. During this year disease was kept under control; new animals coming on to the ranch were quarantined for six weeks and dipped weekly in order to prevent the introduction of tick-borne diseases. During 1951, the twelve months mortality was 47 deaths due to East Coast fever and 20 due to trypanosomiasis, or 5 per cent in total.

In 1952 the ranch was extended to cover some 20,000 acres and by the end of that year there were 787 breeding females, 583 calves and yearlings, and 487 bulls and steers, and mortality rate was reduced to 2·2 per cent, viz, only two cases of East Coast fever and 41 cases of trypanosomiasis. Unfortunately, however, there was an outbreak of contagious abortion which caused the loss of 24 calves.

With the installation of a weigh-bridge it was possible to carry out monthly weighings of animals. A sample of 20 Boran and 20 Zebu calves was taken, and their average monthly gains in liveweight during a five month period were 21 lb. 10 oz. and 14 lb. 14 oz. respectively. The liveweight increase of 50 steers which had been grazed on the ranch for 14 months averaged 10 lb. per head per month.

The failure of the 1953 rains affected grazing conditions adversely and all cattle had to range several miles in search of fodder, but despite this most of the cattle, especially the younger ones, kept in very good condition. The disease position remained good on the whole and there was only one suspected case of East Coast fever, while of the 93 cases of diagnosed

trypanosomiasis that were treated, 92 were cured. Unfortunately contagious abortion continued and there were 50 cases in the heifer herd. The total mortality rate amounted to 3 per cent in 1953. During this year 409 calves were born and by the end of December there were 2,159 head of cattle on the ranch.

As the various destocking programmes (*e.g.* that in Iraqw as described above) progressed, more and more immature and unconditioned cattle began to appear on livestock markets and in order to prevent them from being bought by butchers and slaughtered for meat, a scheme was devised to purchase and hold these young animals, which were mostly males, in order to fatten them for resale as more economic carcases.

A pilot scheme was started by the Veterinary Department in 1952 on the Mkata Plains on higher land to the west which was not at that time in use for the Pilot Ranching Scheme described above.

The area was, of course, not subject to flooding and there were few tsetse flies, except along the Mkata river which unfortunately was the sole source of permanent water.

By the end of 1952, 3,774 immatures purchased on livestock markets in the Lake, Western and Central Provinces were being held under this scheme. The widespread areas from which these animals came, together with the speed of their delivery, meant that it was not possible to examine all arrivals as thoroughly as might have been desired for signs of disease. However, by means of dipping immatures on up-country holding grounds before they were trekked and/or railed to Mkata, and then quarantining them for one month after their arrival, during which period they were sprayed every five days, tick-borne diseases were successfully controlled. Thus, only five cases of East Coast fever were diagnosed during that year and they were all in the first herd to arrive. Despite the fact that all these young animals were forced to water in dense thicket on the Mkata river, only 29 cases of trypanosomiasis were diagnosed.

To overcome this danger of trypanosomiasis at the many watering points along the river a bore-hole was sunk, but did not come into operation until 1953. As has been stated previously the 1952 rains more or less failed and grazing was very poor especially on the high land where immature stock were held and where fierce fires reduced the quantity of grazing. Despite this, stock remained in excellent condition.

In 1953 the grazing position became worse and stock had to walk for greater distances to find food. A further 1,383 immatures were brought in during the year and because of the shortage of grazing up-country many of these were in poor condition on arrival at Mkata. Although acclimatized stock maintained condition despite the poorer circumstances, the new intakes took several months to improve. Furthermore, the tsetse situation worsened and both East Coast fever and foot-and-mouth disease were introduced into the herds, though fortunately without serious consequences; 324 cases of trypanosomiasis were diagnosed of which only 58 were fatal.

The value of this Immature Holding Scheme may be assessed by the fact that 600 head were sold in 1953 at an average price of shs. 178/79 each, some prices rising to shs. 40 per 100 lb. liveweight, while the territorial

average price for the year on livestock markets for mature slaughter stock was only shs. 124/47.

CONCLUSION

In a country like Tanganyika, where overstocking is a problem, it is essential to devise plans for the alleviation of stock pressure on the land. Although destocking or culling programmes may be drawn up, care must be taken to ensure that such programmes do not run against local custom if success is not to be endangered.

Furthermore, such destocking programmes can easily create difficulties in themselves, especially with regard to the disposal of stock sold on markets. Unless the market is perfectly elastic with regard to all classes of livestock, there will be great danger of killing a destocking scheme when demand for cattle begins to dry up.

There is also a tendency for an increasing proportion of immature cattle to be sold, and in order to use these animals economically, some plan for holding and fattening them becomes almost a corollary of the original destocking scheme. In Tanganyika where conditions are suitable for ranching, it has been demonstrated that large-scale holding grounds and ranches are not only possible, even from the disease point of view, but are also an economic proposition.

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Growth of the Dairy Industry in Jamaica (1940–1953)

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INTRODUCTION

Any person in touch with the livestock industry in Jamaica over the past 15 years cannot fail to be impressed by the surge of interest in dairy farming, especially amongst the peasant farmers, during this period. This change in the traditional structure of the livestock industry is generally regarded as highly desirable in that it has resulted in the introduction of ' mixed farming ' to peasants who, before that time, were cultivators without stock, and has given a large segment of peasant farmers a regular and reliable cash income. It has occurred following the establishment of a condensed milk factory in 1940 which first provided a stable and convenient market for milk of high or low quality *ex farm*. The object of this short paper is to discuss the relative importance of the condensery and the various other factors which may have contributed to this growth of dairy farming.

THE DAIRY INDUSTRY IN 1938

No reliable figures are available for the number of cattle or amount of milk produced in the island during 1938. Howe (1937) estimated that the population of ' horned stock ' in Jamaica was 131,000, of which 10 per cent were used for dairying and 5 per cent actually in milk, producing a total of approximately 26,000 quarts per day. He contrasts this with a figure of 113,000 horned stock for 1891, producing an estimated 4,500 quarts of milk: Howe's estimates were apparently based on the cattle returns for taxation purposes and must be discredited. The actual number of cattle in the island at that time was probably nearer 200,000 of which approximately 20 per cent were capable of giving some milk commercially. This tendency to underestimate cattle population figures is referred to in the Beasley (1952) report and makes the reliability of contemporary statistics of the industry doubtful. By 1942 when a census which probably understated numbers by 4 per cent (Burrowes, 1952) was made, the total cattle population was given as 225,736. The switch-over from beef to dairy cattle which occurred throughout the period under review cannot have been great by 1942 when, of the above figure, approximately 75,300 cattle were classified as ' dairy '. At this time, out of 14,194 farms (of over one acre) reporting dairy cattle, 4,905 were between four and six acres.

It seems fair to say, from such evidence as is available, that in 1938 some milk was drawn from about 10 to 15 per cent or, say, 25,000 of the cows in the island for consumption on the farm or in the household in which it was produced. Burrowes (1952) estimated that 17,000,000 quarts were produced during that year, a figure which contrasts with that of approximately

9,500,000 adduced by Howe. There were few dairy farms, and little fluid milk was sold retail. The sales of condensed milk in 1939 were equivalent to 11,163,000 quarts of fresh milk per year. This was all imported.

THE MILK INDUSTRY IN 1952

With respect to 1952, more accurate figures are available. Accurate statistics are available for the receipts of milk by the condensery, and reasonably close figures for cattle population and total milk production are available from the sample surveys undertaken by the Department of Agriculture (BURROWES, 1952, 1953). These surveys which are probably accurate within 2–4 per cent, show that during 1950 there were 46,600 ' dairy ' and 73,600 ' dual purpose ' in a total cattle population of 248,500.

The cattle classified as ' dairy ' were predominantly of dairy breeding (usually Grade Jersey) and were kept for milk production. Those classified as ' dual purpose ' were of a type suitable for either beef or milk production. This classification is to a large extent subjective, depending on the enumerator's outlook and intelligence, but it can be safely said that the figure represents a *bloc* of animals whose production will be directed either to beef or milk as the market leads. Unfortunately, it is not possible to compare these figures in detail with those of the 1942 census since this latter was restricted to ' farms ' of over one acre and the classification of ' dual purpose ' was omitted. It is significant, however, that the parishes in which dairying is widely practised showed a large increase in the ' dairy ' and ' dual purpose ' categories during this period.

Another feature of interest in the structure of the present industry is the size of herd producing milk. From the 1950 sample survey it was estimated that nearly two-thirds of the dairy and dual purpose cattle were kept on farms of less than 25 acres. The breakdown is given in *Table 1* extracted from Burrowes' figures.

Table 1. Number of Dairy and Dual Purpose Cows Classified according to Size of Farm, 1950

	Size of holding in acres									
	0–4	1–4	5–9	10–24	25–49	50–99	100–199	200–499	500+	Total
Dairy	8,200*	7,520	5,136	7,149	3,196	5,123	2,460	3,836	12,168	54,788
Dual	12,100*	11,077	11,844	18,058	8,425	3,850	3,071	6,520	10,761	85,706

* Estimates

Of the cows supplying the condensery in 1951, 50 per cent were in herds of less than five head, 11 per cent were in herds of five to nine head, and 39 per cent were in herds of 10 or over: 72 per cent of herds supplying the condensery were of four animals or less.

It is estimated that, in 1952, approximately one-third of the island's milk production was sold as fresh milk in Kingston, approximately one-third consumed as fresh milk in other parts of the island, and approximately one third sold to the condensery for manufacture. A total of approximately 30,000,000 quarts of milk was produced in the island during the year.

Meanwhile, total consumption of fresh milk had risen to approximately 20,000,000 quarts of fresh milk per annum and to the equivalent of 14,507,000 quarts of fresh milk as condensed milk, of which 83 per cent was produced locally. Some salient figures for the differences over these 15 years are given in *Table 2.*

It will be seen that, during the period under review, local production of milk has increased to the extent of providing nearly 12,000,000 quarts for manufacture and, in addition, has provided an estimated 3,000,000 quarts to meet increased consumption of fluid milk. This gives a total increased annual output of approximately 15,000,000 quarts over the 15 year period. The price of milk for fluid consumption *ex farm* was 3*d.* per quart in 1938, as compared with 7½*d.* to 8*d.* per quart in 1953.

The mechanism and contributory causes of this rise are analysed in the following paragraphs.

Table 2. Figures for Importation, Local Production and Consumption of Milk in 1939 and 1952

	1939 (*quarts*)	1952 (*quarts*)
Importations of milk (as fresh milk equivalent)	11,163,000	2,558,000
Local production of condensed milk (as fresh milk equivalent) ..	Nil	11,949,000
Total consumption of condensed milk (as fresh milk equivalent) ..	11,163,000	14,507,000
Estimated consumption of fresh milk (whole island)	17,000,000	20,500,000
(*per capita*)	23·5	23·0
Estimated number of dairy, beef and dual purpose cattle	225,591*	235,500†
Estimated number of milking cows	25,000	54,000

* 1942 figure (including 5,000 estimated kept on 'farms' of less than one acre).

† 1950 figure.

(This table does not show, except in the form of condensed milk produced, importations of dried skim milk powder totalling 886,000 lb. in 1952 which were used to 'extend' milk of high fat content.)

GROWTH OF THE INDUSTRY

The input of milk to the condensery since its establishment and other data are shown in *Table 3.*

As can be seen from these figures, there has been a steady progressive rise in the receipts of milk over the period, a rise which is reflected in the number of farmers supplying milk and in the number of miles travelled in collecting supplies. Many collection routes were known to be uneconomical, some collecting less than five quarts per mile, but were operated for political reasons or in the hope that dairy farming would follow the establishment of a route in certain districts.

Table 3. Number of Suppliers, Input of Milk, Price ex farm, *Cost Delivered at Factory and Number of Miles Travelled in Milk Collection, by Years*

Year	*No. of condensery suppliers at end of each year**	*No. of quarts*	*Price paid to producer for milk* (ex farm) *for condensery* (*pence per quart*)†	*Cost of milk delivered at factory* (*pence per quart*)	*Approximate mileage covered in milk collections* (*condensery*)	*Remarks*
1939	Nil	Nil	—	—	Nil	
1940 (8 mths)	183	546,582	2½d. flush 2¾d. dry season	3·102	167,300	
1941	290	3,170,865	2¾d. dry season	3·065	236,871	
1942	389	3,483,206	3d. flat rate	3·459	243,494	
1943	481	3,511,134	3½d. flat rate	3·926	248,156	
1944	668	3,819,890	3¾d. flush 4d. dry season	4·659	301,589	Hurricane
1945	754	5,073,922	4d. flat rate	4·887	364,798	
1946	1,036	5,603,164	4d. flat rate	5·082	439,499	
1947	1,343	7,260,675	4d. flat rate	5·058	579,098	
1948	1,732	8,813,690	4½d. flat rate 5d. flat rate	5·950	744,653	
1949	2,123	10,284,125	5d. flat rate	6·192	773,047	
1950	2,006	11,519,332	5d. flat rate	6·273	865,608	
1951	2,131	10,650,026	5½d. flush 6d. dry season	6·976	886,677	Hurricane
1952	2,181	11,948,312	6d. flush 6½d. dry season	7·837	926,794	
1953	2,325	11,554,392	6d. flush 6½d. dry season	8·043	1,067,835	

* Many suppliers collect milk from a number of sub-suppliers, especially during the flush season.
† The price quoted for any particular year was fixed during that year and did not necessarily apply throughout the whole year.

As the input rose the cost of milk delivered at the factory rose. This was largely due to increases in the prices paid *ex farm* (see *Table 3*), but also to the rising costs of transportation and the increasing need to forage for milk. The mileages in column 6 of *Table 3* can be used as an indication of the activities of the condensery in attempting to satisfy its milk requirements.

This extension of milk routes over relatively long distances resulted in a small collection of milk per mile and proved a serious factor in raising the cost of milk delivered at the factory. In addition to the actual haulage costs the time factor, coupled with the low hygienic quality of much of the milk *ex farm*, made necessary the erection of intermediate milk-cooling stations, resulting in a further increase in delivered costs. There can be no doubt that the present cost of milk delivered would be substantially decreased if collections were made only from areas where potential production was high and haulage costs low, and it is probable that if economic routes only were operated, higher prices could be paid to producers in such areas. Certainly the wisdom of a uniform price for milk, irrespective of its quality or of the accessibility of the farm on which it was produced, now appears doubtful.

FACTORS CONTRIBUTING TO THE INCREASED PRODUCTION OF MILK

The factors contributing to this increased production may be listed as shown overleaf.

Economic

(1) Effect of convenient and assured market.

(2) Effect of fixed price.

(3) Relative attractiveness of other agricultural pursuits.

Technical

(4) Make-up of the national herd.

(5) Area of supply from which regular collections are made.

(6) Effect of propaganda for better management.

(7) Effect of livestock (breeding) improvement services.

Any increased production of milk which could be looked for in 1938 when the establishment of a condensery was being debated, had to come, in the first instance, from cattle potentially able to produce milk at that time. Increases in production from the first five causes listed above were the only ones occurring during the first three or four years, and it cannot have been until later that any effects of improved breeding were felt. The effect of propaganda for better care and management will be discussed later.

The milk sent to the condensery in 1941 came partly from a diversion of milk from domestic consumption or local sale and partly from the milking of ' dual purpose ' animals which had previously been required only to rear calves. The fact that the condensery collected milk once a day enabled farmers to separate calf and cow in the evening and to milk the cow in the morning before turning them out together. This practice proved economic and at the same time permitted the peasant to rear a calf under conditions of management which would have been fatal had the cow been milked twice daily. Thus the factors (1) and (2) probably contributed largely to the growth of input over the first three years. Burrowes' (1952) survey of 1951–2 disclosed that 91 per cent of producers stated that their operations had been materially influenced by the condensery, and nearly 42 per cent stated that the establishment of a milk route had been responsible for their engaging in dairy farming.

Another factor of importance at that time was the agricultural hiatus left by the decline of the banana industry.

Owing to the spread of Panama and leaf-spot diseases, and the war-time stoppage of exports, exports of bananas had dropped from over 30 million stems in 1937 to less than one million stems in 1943. Large areas of banana lands, particularly in St. Mary and in the western parishes, were seeking an alternative product, and dairying filled the bill. The effect of this was not fully felt until 1941–43, but many farmers were, at the opening of the condensery, looking for a new product.

Another economic factor during this period was the declining interest in beef due to the fragmentation of many larger estates and to the low returns from the price fixed by Government which was widely claimed to be uneconomic and certainly did not encourage the practice of improved beef-raising methods. In 1940 the price of beef was first controlled at 50*s*. per 100 lb., being raised in 1942 to 55*s*. and 50*s*., and later to 65*s*., 60*s*., or 55*s*. depending on grade, these figures being paid on half the live weight of the animal. In 1943 a price of 60*s*. per 100 lb. warm dressed carcase weight

was paid, and this rose to 70*s.* in 1944, to 85*s.* in 1946, to 90*s.* in 1948, to 95*s.* in 1950, and to 102*s.* 6*d.* in 1951. None of these increases excited confidence in beef production, and until the big increase to 135*s.* per 100 lb. in 1952, there was a tendency for cattle farmers to concentrate on dairying wherever their conditions allowed.

Efforts by the Department of Agriculture to stimulate dairying were largely of a long-term nature. In 1939, in association with the condensery, thirty stud stations were established at which dairy bulls of good breeding were kept to give free service to cows belonging to herds of less than five head. Bulls were loaned to larger farmers, and later approved bulls in certain areas were subsidized, the owner being paid a service fee by Government with respect to peasant's cows brought to his bull. Such schemes were widely popular and, in 1941–42, 12,961 services were given by Government-sponsored animals. The annual reports of the Department of Agriculture over this period 1941–49 mention the ' increase in mixed farming ', the ' increased consumption of fresh milk ' resulting from increased milk production, the ' rapid progress in dairying ', and the popularity of Grade Jerseys. In 1947 dairying was described as ' the mainstay of the smaller agriculturists '.

The influence of the Government breeding programme over the years 1940–1950 cannot be doubted by anyone who has travelled around Jamaica. The Grade Jersey rapidly asserted itself as the most productive and popular breed and Grade Jersey animals predominate in the dairying districts. Unfortunately, no figures for production per head on farms are available, so the actual increase in production attributable to this breeding programme cannot be assessed, but it must have been considerable.

The Government, the Jamaica Livestock Association and the Jamaica Agricultural Society also attempted to encourage improved feeding of cattle. The Department of Commerce and, later, the Jamaica Livestock Association, marketed dairy feeds based on coconut meal and compounded largely from local materials. The sale of such feeds increased steadily over the years and with experience a reliable product at reasonable cost was produced. Efforts were made by the Department of Agriculture and the Jamaica Agricultural Society to foster the planting of forage crops, especially Napier grass and Uba cane, and the making of silage. Such efforts were, perhaps, not as successful as they might have been owing to lack of basic information in the fields of pasture and nutrition work and to the resistance of the farmer to the adoption of conservation practices. The effect of these livestock improvement measures was considerable, but they probably gained impetus largely during the years 1945–1952. A further large increase in milk production in the island could even now follow the more widespread application of the present knowledge of improved feeding practices.

During all this time the condensery was making increasing efforts to obtain supplies of milk. This was, to some extent, effected by increases in the price paid to the producer which was fixed by agreement with Government at a figure considered to give a reasonable return, and also by the opening of more and more routes for milk collection. The collection costs on most of the routes opened in the years 1945–1950 were uneconomic in the first instance and many have remained so.

The price paid to the producer rose over the period as indicated above, but it proved, as time went on, impossible to fix at a level which was giving a fair return to all producers. A most marked effect of the condensery operations had been to encourage dairying by the small farmer. Many of these farmers keeping less than five cows, own little or no grazing land and keep their cows on roadside (so-called ' long pasture ') or other free grazings, purchasing or growing the minimum of feed. Burrowes (1953) estimates that in 1951–1952 at least 18 per cent of all suppliers used roadside grazings. Such producers have few over-head charges in milk production and are satisfied with a milk price which would not give a fair return to a farmer who farmed in a more orthodox manner and who expected a return on his capital investment.

SUMMARY

An attempt has been made to assess the factors contributing to the growth in the dairy industry in Jamaica over the years 1938–53. This increase resulting in doubling of the milk output, has been largely derived from an actual increase in production rather than from a diversion of supplies. By far the most potent factors have been the provision of an assured and convenient market to the condensed milk factory and the decline of competition by other agricultural enterprises especially banana growing, but the livestock improvement services of Government have had powerful ancillary effect in raising the efficiency of production.

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Replanting of Oil Palms

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INTRODUCTION

Little information is available concerning the best procedure for replanting of oil palm plantations which are too old for economic exploitation. The ideal system would be to retain the old stand until the young palms come into production, provided the beginning of the productive stage of the young palms is not too much retarded and their future productivity not permanently reduced.

Experience in the Far East tends to show that there is some advantage if the old stand or part of it is retained for a restricted period, whereby the production continues, thus reducing the total period of non-productivity. Our first object was, therefore, to investigate whether felling before replanting is profitable or otherwise.

Furthermore, if felling before replanting proves to be profitable, one might still question whether lack of light or poor soil conditions are the cause of the failure on the non-felled areas. Therefore our second object was also to find out whether the improving of soil conditions for the young palms by means of fertilizing is profitable or not.

DESCRIPTION OF THE EXPERIMENT

In accordance with the above considerations, it was decided to lay down a simple replanting experiment in order to obtain some preliminary information concerning the questions involved. Our experiment included the following four treatment combinations arranged into a 4×4 latin square:

(*i*) No felling of the old stand, no fertilizing of the young palms.
(*a*) Old stand felled before replanting, no fertilizing of the young palms.
(*b*) No felling of the old stand, young palms fertilized.
(*ab*) Old stand felled before replanting, young palms fertilized.

Each plot consists of six lines with 13 palms, hence 78 palms net. The lines are 8 m apart and the spacing within the lines amounts to 4 m (312 palms per ha.). This high initial density was chosen in view of the mortality to be expected and to allow for a selective thinning out in the future. Between the last line of a row of four plots and the first line of the next row is one guard line, and between the last palm of any line of any plot and the first palm of the next plot in the same line is one guard palm. Consequently the whole experimental area comprises 29 lines of 57 palms, or 232 by 228 m (5·2896 ha.), including guard lines and guard palms.

The experimental site is an old improved riverine natural palmery on the southern Kasai bank (Brabanta near Basongo). The old palms on the plots assigned to the (*a*) and (*ab*) treatments were felled in the beginning of November 1948. Lining, picketing and holing ($40 \times 40 \times 40$ cm) was done in the second half of the same month, immediately followed by

planting with locally selected material. The old stand on the plots assigned to the (*i*) and (*b*) treatments was removed by means of poisoning with sodium arsenite during the course of 1952.

Fertilizing

The quantities of the nutrients applied per palm in the plots assigned to the (*b*) and (*ab*) treatments are summarized in *Table 1*. From this it appears that the fertilizing has not always been the same. The subsequent modifications represent stages of increasing knowledge concerning the most economic formula for this region, as obtained from other experiments and investigations, and do not pretend to indicate the ideal nutrient supply for oil palm replantings of increasing age. On the contrary, it has been shown recently that only potash, magnesium, boron and, to a lesser degree, phosphate are the essential nutrients for this type of soil, and that especially boron deficiency can cause very serious and sudden growth disturbances of the type commonly known as Bud Rot and Little Leaf (KOVACHICH, 1952 and 1953, and FERWERDA, 1954). Therefore the effect of fertilizing, as discussed in the following paragraphs, although very important, represents by no means the optimum effect.

Table 1. Grammes Nutrient per palm and per annum

	1948	1949	1950	1951	1952	1953
N	23	70	192	256	308	308
P	26	23	48	—	78	78
K	66	91	175	234	298	298
Mg	10	35	65	—	—	—
Ca	163	82	131	—	80	294
Cu	—	—	25	—	—	—
B	—	—	1·1	—	—	—
Zn	—	—	0·8	—	—	—
Ni	—	—	0·8	—	—	—
Co	—	—	0·8	—	—	—
Mo	—	—	1·9	—	—	—

Nitrogen was applied as ammonium phosphate (1948, 1949, 1950), nitrochalk (1949, 1950, 1952, 1953), and ammonium sulphate (1951); phosphate as ammonium phosphate (1948, 1949, 1950), and superphosphate 45 per cent (1952, 1953); potassium as sulphate of potash (all years); calcium as dolomitic limestone (1948) and calcium carbonate (1949) apart from the quantities contained in the other fertilizers; magnesium as dolomitic limestone (1948), and magnesium sulphate (1949, 1950); copper as copper sulphate (1950); boron as borax (1950); cobalt as cobalt sulphate (1950); nickel as nickel sulphate (1950); zinc as zinc sulphate (1950), and molybdenum as ammonium molybdate (1950).

Observations

In order to obtain a grading of the treatment effects at regular intervals, the following series of observations were made:

(*i*) Number of new leaves produced by the young palms (first observation April 1949, last observation October 1951).

(*ii*) Length of youngest fully developed leaf (first observation October 1949, last observation October 1951).

(*iii*) Percentage of losses (first observation April 1949, last observation April, 1954).

(*iv*) Disease incidence (first observation October 1949, last observation April 1954).

(*v*) Number of male and female inflorescences (first observation October 1951, last observation April 1954).

(*vi*) Chemical composition of the first and ninth leaf (1951, 1953).

DISCUSSION OF THE RESULTS

The single treatments are indicated in the tables by their symbols (*i*), (*a*), (*b*) and (*ab*) (see paragraph 2). The main effects of felling and fertilizing are represented by the symbols *A* and *B*, whereby

$$A=\frac{ab-b+a-i}{2}$$

$$B=\frac{ab+b-a-i}{2}$$

The interaction between felling and fertilizing, viz. the difference between the effects of fertilizing on the felled and on the non-felled areas, or, similarly, the difference between the effects of felling on the fertilized and the non-fertilized areas is indicated as *AB*, whereby

$$AB=\frac{ab-b-a+i}{2}$$

In the main tables the general mean is indicated as $\bar{x}$, the standard deviation as *s*, and the standard deviation expressed as a percentage of the general mean as *s* per cent.

LEAF PRODUCTION

The numbers of leaves produced per 100 living palms in consecutive periods of six months are summarized in *Table 2*. The data in *Table 3* have been derived from those in *Table 2* in order to facilitate comparison between treatments.

As appears from *Table 2*, the leaf production per period of six months shows a steady increase with the age of the palm. There is, however, a decrease to be noted when comparing the period October–March with the immediately following period April–September.

The beneficial effect on the development of the young palms in felling the old stand previous to replanting is already evident six months after planting, and increases with the age of the palms. The responses to fertilizing, however, only become noticeable in the leaf production 18 months after planting. The interaction between felling and fertilizing becomes positive 18 months after planting, indicating that the effect of fertilizing is greater on the felled than on the non-felled areas, but is insignificant in 1951.

Table 2. New Leaves Produced per 100 Living Palms per Period of Six Months

Treatment		Apr. '49*	Oct. '49	Apr. '50	Oct. '50	Apr. '51	Oct. '51
No felling, no fertilizing	(*i*)	246	184	382	241	426	333
Felling, no fertilizing	(*a*)	317	248	582	484	822	725
No felling, fertilizing	(*b*)	240	172	516	297	660	489
Felling and fertilizing	(*ab*)	296	250	818	677	1111	935
Sign. diff. P=0·05		34	35	99	38	95	121
Main effect felling	(*A*)	64	72	251	312	424	419
Main effect fertilizing	(*B*)	–14	–5	185	125	262	183
Interaction	(*AB*)	–8	7	51	68	27	27
Sign M.E. or Int. P=0·05		24	25	70	27	67	86
General mean	($\bar{x}$)	275	213	574	425	755	620
Standard deviation	(*s*)	19	20	57	22	55	70
Standard deviation per cent	(*s*%)	7·1	9·5	9·9	5·2	7·3	11·3

* Four months only.

Table 3. Cumulative Number of Leaves per 100 Living Palms Since Planting

Treatment		Apr. '49	Oct. '49	Apr. '50	Oct. '50	Apr. '51	Oct. '51
No felling, no fertilizing	(*i*)	246	430	812	1053	1479	1812
Felling, no fertilizing	(*a*)	317	565	1147	1631	2453	3178
No felling, fertilizing	(*b*)	240	412	928	1225	1885	2374
Felling and fertilizing	(*ab*)	296	546	1364	2041	3152	4087
Main effect felling	(*A*)	64	134	385	697	1120	1540
Main effect fertilizing	(*B*)	–14	–18	166	291	552	736
Interaction	(*AB*)	–8	0	50	119	146	174
General mean	($\bar{x}$)	275	488	1062	1487	2242	2863

Table 4. Mean Length of the Youngest Unfolded Leaf (cm)

Treatment		Oct. '49	Apr. '50	Oct. '50	Apr. '51	Oct. '51
No felling, no fertilizing	(*i*)	80	82	89	111	117
Felling, no fertilizing	(*a*)	86	100	109	159	193
No felling, fertilizing	(*b*)	85	104	102	145	156
Felling and fertilizing	(*ab*)	87	125	126	193	238
Sign. diff. P=0·05		15	12	15	25	26
Main effect felling	(*A*)	4	19	22	48	79
Main effect fertilizing	(*B*)	3	24	15	34	42
Interaction	(*AB*)	–2	2	2	0	3
Sign. M.E. or Int. P=0·05		11	9	11	17	19
General mean	($\bar{x}$)	84	103	106	152	176
Standard deviation	(*s*)	8·8	7·6	8·7	14·2	15·2
Standard deviation per cent	(*s*%)	10·5	7·4	8·2	9·3	8·6

It is interesting to note that the relative effect of felling is more pronounced in the period April–September (including the dry season) than in the immediately preceding period October–March. On an average felling has improved the leaf production about twice as much as fertilizing; but the effect of both felling and fertilizing must be considered as being very important.

Judging from the total leaf production (*Table 3*) it appears that 34 months after planting (October 1951) the palms on the non-felled areas were on an average some 12 months behind in development as compared with those on the felled areas, whilst the non-fertilized palms were about six months behind in development as compared with the fertilized palms. The combined action of felling and fertilizing caused an improvement over and above the non-felled palms of 17 months.

Length of the Leaves

Table 4 shows the length of the youngest fully opened leaf at the end of consecutive periods of six months. Both felling and fertilizing have caused an increase of the length of the leaves from the sixteenth month after planting, and these effects increase with time. There is, however, no indication of an interaction between felling and fertilizing so far as the length of the leaves is concerned.

Judging from the length of the leaves 34 months after planting (October 1951) the palms on the non-felled areas were on an average some 10 months behind in development as compared with those on the felled areas, whilst the non-fertilized palms were about eight months behind as compared with the fertilized palms. The combined action of fertilizing and felling resulted in an improvement in development over and above the non-felled and non-fertilized palms of more than 19 months.

It is interesting to note that there is somewhat less difference between the effects of fertilizing and felling for the length of the leaves than for the number of leaves. This is due to the fact that better light conditions rather tend to increase the number of pinnae per unit of length of the leaf, than the length itself.

MORTALITY

The total mortality per 100 palms planted at the end of the consecutive periods of six months is summarized in *Table 5*.

Table 5. Losses per 100 Palms Planted

	Apr. '49	Oct. '49	Apr. '50	Oct. '50	Apr. '51	Oct. '51	Apr. '52	Apr. '53	Oct. '53	Apr. '54
i	6	11	16	18	18	19	19	19	19	20
a	4	5	6	6	6	6	7	6	7	—
b	7	10	17	18	20	20	20	22	23	24
ab	5	5	9	8	8	9	12	12	14	—
S.D.	2	8	8	5	—	—	—	—	—	—
A	–2	–5	–9	–11	–11	–12	–10	–11	–11	—
B	1	2	2	1	3	3	4	5	5	—
AB	0	0	1	1	0	1	2	2	2	—
S.E.	2	5	6	4	—	—	—	—	—	—
$\bar{x}$	5	8	12	13	13	13	14	15	16	—
s	1	6	5	4	—	—	—	—	—	—
s%	26	73	39	31	—	—	—	—	—	—

It appears that the death rate becomes very much lower after the sixteenth month after planting (April 1950). A serious outbreak of Little Leaf due to a nutrient imbalance, which was mainly limited to the felled and fertilized

plots in early 1952 however (see Disease incidence) caused a new increase of the death rate. This can also be noted on the non-felled and fertilized plots after April 1953, which corresponds with the beginning of the productive stage of these areas.

Felling alone has caused a significant decrease on the mortality during the first three years after planting, the mortality on the felled areas being, on an average, some 11 per cent less than on the non-felled areas. The slight increase in mortality caused by fertilizing during this time is not significant, but it becomes so in the fourth year after planting. This undesirable effect of fertilizing must not be overestimated, however, as the formulae applied were purely tentative and not necessarily correct for all the periods of growth.

Disease incidence

Although the census of the incidence of the various diseases is bound to be somewhat subjective, especially because the successive series of observations were made by different persons, it nevertheless provides a valuable indication of the differences existing at a certain time, and to a lesser degree also of the changes occurring in the course of the time.

The most important series of observations from a practical point of view concerns the percentage of healthy palms (*Table 6*). This was quite satisfactory on the non-felled areas during the two first years after planting, but decreased to a low level in the following years, with a slight improvement after removal of the old stand. The main effect of felling, however, remains positive throughout the whole period of observation.

Table 6. Percentage of Healthy Palms

	Oct. '49	Oct. '50	Oct. '51	Apr. '52	Apr. '53	Oct. '53	Apr. '54
i	76	74	23	11	19	32	45
a	59	84	70	64	73	82	(82)
b	75	89	64	36	32	56	37
ab	57	96	72	24	27	58	(69)
A	–14	8	28	21	25	25	(34)
B	–1	14	21	–7	–17	0	–11
AB	–1	–2	–20	–33	–29	–24	(–2)

Fertilizing has considerably improved the percentage of healthy palms during the second and third years after planting, but in the course of the fourth year a drop occurred due to a sudden outbreak of Little Leaf, from which the palms never completely recovered up to the present. The interaction between felling and fertilizing already became negative during the third year after planting, and remained so until October 1953, meaning in this case that the effect of fertilizing was positive on the non-felled, but negative on the felled areas as far as the percentage of healthy palms is concerned. This rather unusual effect of fertilizing can be understood if it is borne in mind that growth on the non-felled areas was greatly retarded by the poor light conditions, so reducing the possibilities for nutrient uptake, and at the same time increasing the chance of a nutrient deficiency.

Table 7. Incidence of Wilt per 100 Living Palms

	Oct. '49	Oct. '50	Oct. '51	Apr. '52	Apr. '53	Oct. '53	Apr. '54
(*i*)	0	15	75	85	78	66	51
(*a*)	0	4	25	21	14	15	12
(*b*)	0	7	34	27	26	15	12
(*ab*)	0	2	12	10	12	13	12
(*A*)	0	–8	–36	–50	–39	–26	–20
(*B*)	0	–5	–27	–24	–27	–26	–20
(*AB*)	0	3	14	13	25	24	19

Wilt (*Table 7*) was little in evidence in the beginning, but evidently became the major disease on the non-felled and non-fertilized areas. Its incidence is reduced both by felling and fertilizing, suggesting that the external symptoms described as wilt may have quite different causes, including growth disturbances caused by fungi and nutrient deficiencies.

Table 8. Incidence of Little Leaf and Bud Rot per 100 Living Palms

	Oct. '49	Oct. '50	Oct. '51	Apr. '52	Apr. '53	Oct. '53	Apr. '54
(*i*)	5	4	0	4	3	2	2
(*a*)	1	0	0	7	12	3	4
(*b*)	3	2	3	17	42	28	50
(*ab*)	1	1	16	63	61	29	17
(*A*)	–3	–2	6	24	14	1	–16
(*B*)	–1	–1	9	34	44	26	31
(*AB*)	1	1	6	10	5	0	–17

Little Leaf and Bud Rot (*Table 8*) only became serious in April 1952 on the felled and fertilized areas, and to a lesser extent also on the non-felled and fertilized plots. On the latter plots the incidence of these diseases increased after removal of the old stand. It is obvious that the incidence of Little Leaf and Bud Rot is more or less related to the beginning of the productive stage, but it is equally obvious, as was already suggested by Kovachich (1953) that these diseases are induced by a nutrient imbalance. It has been shown in the meantime (Ferwerda, 1954) that boron deficiency is the cause in the majority of cases. As boron was only once included in the fertilizer formula in very small quantities, and as borax is very soluble, it is not surprising that the palms never recovered from this nutrient deficiency, as effective curative measures could only be taken after discovery of the cause of Little Leaf in February 1954.

Table 9. Incidence of Chlorosis per 100 Living Palms

	Oct. '49	Oct. '50	Oct. '51	Apr. '52	Apr. '53	Oct. '53	Apr. '54
(*i*)	20	8	2	0	0	0	1
(*a*)	41	12	3	2	1	0	0
(*b*)	22	2	0	0	0	0	0
(*ab*)	42	2	0	1	0	0	2
(*A*)	21	2	1	1	0	0	0
(*B*)	1	–8	–2	–1	0	0	0
(*AB*)	0	–2	–1	–1	0	0	1

Chlorosis (*Table 9*) of the type now known as magnesium deficiency, was rather general during the first year after planting, especially on the felled areas. During the second year the incidence of this disease was much less and mainly limited to the non-fertilized areas. In the following years only isolated cases of chlorosis were found.

These phenomena can be understood if it is borne in mind that this type of chlorosis is caused by magnesium deficiency. During the first year after planting, the potash released from the old stand on the areas felled previous to replanting has induced a relative magnesium deficiency, which disappears in the following years after leaching-out of the excess of potash. Therefore the symptoms were limited to the non-fertilized areas in the second year, indicating the existence of a slight absolute magnesium deficiency in the soil.

Other diseases were little in evidence (Patch Yellow, Plant Failure) and too small in number to be studied in relation to the treatments.

CHEMICAL COMPOSITION

The chemical composition of the first fully opened leaf in the period before removal of the old stand from the ' non-felled ' areas can be compared with that in the period after removal of the old stand. The results are shown in *Table 10*. From this it appears that felling of the old stand has greatly increased the potash content of the leaves, even more than fertilizing. The same deduction can be made from the absence of a response to felling in 1953. Removal of the old stand on the ' non-felled ' areas has levelled out the differences between felling and non-felling as far as the potash content of the leaves is concerned. The response to fertilizing is small and non-significant in 1953. The interaction between felling and fertilizing is negative, indicating that the potash content is very close to its maximum in the present case.

Table 10. Chemical Composition of the First Fully Opened Leaf (per cent on Ash)

	Phosphorus		*Potassium*		*Magnesium*		*Calcium*	
	1951	1953	1951	1953	1951	1953	1951	1953
i	6·8	5·0	19·4	25·3	4·2	3·6	14·0	11·1
a	4·4	3·9	34·4	27·4	3·5	3·9	9·0	8·6
b	4·1	3·7	30·7	28·6	5·0	3·5	8·0	7·4
ab	3·2	3·2	34·6	27·6	3·8	4·0	6·4	7·4
S.D.	0·7	0·7	4·4	n.s.	0·4	n.s.	1·9	3·4
A	–1·6	–1·8	9·4	0·6	–0·9	0·4	–3·3	–1·2
B	–1·9	–1·0	5·8	1·8	0·5	0·0	–4·3	–2·4
AB	0·8	0·3	–5·6	–1·6	–0·2	0·1	1·7	1·2
S.E.	0·5	0·5	3·1	n.s.	0·3	n.s.	1·5	2·4
$\bar{x}$	4·6	4·0	29·8	27·2	4·1	3·8	9·4	8·6
s	0·4	0·4	2·4	3·3	0·2	—	1·1	2·0
s%	9	10	8	12	6	—	11	23

S.D. = significant difference P 0·05 ; S.E. = significant effect P 0·05 ; n.s. = non significant ; — = not calculated.

The magnesium content is significantly decreased by felling in the first period, because of the increased uptake of potash released by the old stand. This confirms the higher incidence of chlorosis on the felled areas in the

first year after planting. In 1953 the effect of the felling is insignificant as far as the magnesium content is concerned, as could be expected. Fertilizing has slightly increased the magnesium content in the first period, which confirms the higher incidence of chlorosis on the non-fertilized areas in the second year after planting. In the second period the differences are insignificant, as was the case for the incidence of chlorosis.

The calcium content shows great differences in the first period, due both to felling and fertilizing, and to a somewhat lesser extent also in the second period. They are closely related to the differences in potash and magnesium content and would not seem to require any further explanation at this stage.

The phosphate content is decreased by felling and fertilizing, especially in the first, but to a somewhat lesser extent also in the second period. This would seem to indicate that the availability of phosphate in the soil, although sufficient as long as growth is limited by poor light conditions and deficiency of other nutrients, approaches a minimum as soon as the growth is improved by means of removal of the old stand, providing both better light conditions and a supply of nutrients. It indicates also, however, that the fertilizer formula applied is not sufficiently rich in phosphate. The P-content of the leaves on the felled and fertilized plots (3·2 per cent) is low in an absolute sense and previous experience tends to show that positive responses to applications of phosphate may be expected at this level.

NUMBER OF MALE INFLORESCENCES

The number of male inflorescences present at the end of each period of six months, and the cumulative number of male inflorescences are summarized in *Tables 11* and *12*. The first inflorescences were already present on the felled, and especially the felled and fertilized plots before April 1951, but no census was made at that time.

Table 11. Number of Male Inflorescences per 100 Living Palms

Treatment		Oct. '51	Apr. '52	Oct. '52	Apr. '53	Oct. '53	Apr. '54
No felling, no fertilizing	(*i*)	—	—	0	3	9	12
Felling, no fertilizing	(*a*)	56	178	83	116	75	105
No felling, fertilizing	(*b*)	8	28	11	41	46	76
Felling and fertilizing	(*ab*)	392	422	82	149	70	119
Main effect felling	(*A*)	220	286	77	110	46	63
Main effect fertilizing	(*B*)	172	136	4	36	16	34
Interaction	(*AB*)	164	108	–6	–2	–21	–20

Table 12. Cumulative Number of Male Inflorescences per 100 Living Palms

Treatment		Oct. '51	Apr. '52	Oct. '52	Apr. '53	Oct. '53	Apr. '54
No felling, no fertilizing	(*i*)	—	—	0	3	11	34
Felling, no fertilizing	(*a*)	56	235	318	434	509	614
No felling, fertilizing	(*b*)	8	36	47	88	134	210
Felling and fertilizing	(*ab*)	392	814	896	1045	1116	1235
Main effect felling	(*A*)	220	506	583	694	739	802
Main effect fertilizing	(*B*)	172	308	312	348	364	398
Interaction	(*AB*)	164	272	266	264	243	223

It appears that both felling and fertilizing have increased the average number of male flowers per surviving palm in each of the periods, especially the former. The effect of fertilizing on the felled areas becomes small, however, after April 1952, which coincides with the high incidence of Little Leaf on the felled and fertilized plots. It is interesting to note that the average number of male flowers per surviving palm was already very high on the felled and fertilized plots in October 1951 and April 1952 and that the same average was never reached by any of the other treatments.

Judging from the cumulative totals the development of the palms on the non-felled and non-fertilized areas (*i*-plots) was, in April 1954, more than 30 months behind as compared with those on the felled and non-fertilized areas (*a*-plots), and more than 24 months as compared with those on the non-felled fertilized areas (*b*-plots). Although the male flowers were not counted before October 1951, our records show that they were present on the felled and fertilized plots (*ab*-plots) as early as April 1950, suggesting that the combined effect of felling and fertilizing has advanced the maturity of the palms by at least 48 months. From this it would appear that the differences in physiological age existing in October 1951, as estimated from the cumulative number of leaves and the length of the leaves, were far more important for the future life of the palm than could be expected at that time.

FEMALE INFLORESCENCES AND BUNCHES

In the course of the period April–September 1951 a number of palms on the felled and fertilized plots (*ab*-plots) commenced to produce female inflorescences and bunches. This was the case for the felled but non-fertilized plots (*a*-plots) and the non-felled, fertilized plots (*b*-plots) in the course of the following period of six months (October 1951–March 1952) and for the non-felled non-fertilized plots in the period October 1952–March 1953. The number of female inflorescences and bunches present per 100 living palms for each of the four treatments at the end of the subsequent periods of six months are summarized in *Table 13*.

Table 13. Number of Female Inflorescences and Bunches per 100 Living Palms

Treatment		Oct. '51	Apr. '52	Oct. '52	Apr. '53	Oct. '53	Apr. '54
No felling, no fertilizing	(*i*)	—	—	1	2	9	30
Felling, no fertilizing	(*a*)	—	43	131	247	190	221
No felling, fertilizing	(*b*)	—	7	14	28	51	135
Felling and fertilizing	(*ab*)	22	226	239	230	221	214
Main effect felling	(*A*)	11	131	178	223	176	134
Main effect fertilizing	(*B*)	11	95	60	4	36	49
Interaction	(*AB*)	11	88	48	–23	–5	–56

It appears that the number of female inflorescences and bunches present at the end of each period of six months, which represents approximately the production during the immediately following six months, shows great differences between the various treatments. Both felling and fertilizing, but especially the former, have greatly increased production. This increase is for the greater part due to an earlier producing of the palms on the felled and fertilized areas, which is clearly illustrated by the data

summarized in *Table 14*, giving the percentage of producing palms at the end of each of the above periods. It is impossible to judge whether similar differences will be obtained in the future, as the number of female inflorescences and bunches being dependent on the number of leaves produced before the onset of production, is no direct measure for production at this stage.

Table 14. Percentage of Producing Palms

Treatment ..		Oct. '51	Apr. '52	Oct. '52	Apr. '53	Oct. '53	Apr. '54
No felling, no fertilizing	(*i*)	—	—	0	1	2	9
Felling, no fertilizing	(*a*)	—	10	23	43	46	61
No felling, fertilizing	(*b*)	—	3	4	9	16	36
Felling and fertilizing	(*ab*)	8	49	46	51	56	61
Main effect felling	(*A*)	4	28	32	42	42	38
Main effect fertilizing	(*B*)	4	21	14	8	12	14
Interaction	(*AB*)	4	18	10	0	–2	–14

It will further be noticed that a rate of increase of production considerably greater on the felled than on the non-felled areas, and somewhat greater on the fertilized than on the non-fertilized areas, was obtained in April 1954, the production in the previous periods being limited to a small number of isolated palms, situated mainly near the limits of the felled plots, whilst the felled but non-fertilized areas had reached the same stage two years earlier. When comparing the felled and fertilized with non-felled and fertilized areas the same deduction can be made. The actual effect of retaining the old stand on the development of the young palms is even worse than suggested by the retarded beginning of the productive stage. In fact, the palms of the non-felled areas were in April 1954 at least two years behind in development as compared with those on the felled areas. The effect of fertilizing is somewhat less pronounced, but the number of producing palms on the felled and fertilized areas in 1952 was approximately the same as that on the felled and non-fertilized areas in 1953, suggesting that the difference in development had increased to approximately a year by that time. After April 1952 the number of producing palms and the average production per living palm was practically constant on the felled and fertilized plots, mainly as a consequence of the high incidence of Little Leaf. Moreover, the number of bunches per palm per period of six months is likely to reach its optimum in the course of the sixth year after planting under ideal conditions, so that only the total bunch weight provides a direct basis of comparison after this time.

A good impression of the effects of felling and fertilizing can be obtained from the cumulative numbers of female inflorescences and bunches present at the end of the subsequent periods of six months, as these include the effects in previous periods and are not biased by the normal trend of the number of bunches per palm with increasing age. These data are shown in *Table 15*. From this it is apparent that, as compared with the felled and fertilized plots, the development of the surviving palms on the felled and non-fertilized plots (*a*) was 12 months retarded in April 1954, that on the non-felled fertilized plots (*b*) 24 months, and that on the non-felled, non-fertilized plots (*i*) 30 months.

Table 15. Cumulative Number of Female Inflorescences and Bunches

Treatment		Oct. '51	Apr. '52	Oct. '52	Apr. '53	Oct. '53	Apr. '54
No felling, no fertilizing	(*i*)	—	—	1	3	12	42
Felling, no fertilizing	(*a*)	—	43	174	421	611	831
No felling, fertilizing	(*b*)	—	7	21	49	100	236
Felling and fertilizing	(*ab*)	22	247	486	716	938	1151
Main effect felling	(*A*)	11	142	319	542	718	852
Main effect fertilizing	(*B*)	11	106	166	170	208	256
Interaction	(*AB*)	11	99	146	124	119	63

CONCLUSIONS

The benefits of retaining the old stand for a certain time in the case of a replanting are greatly reduced by the increased mortality of the young palms, necessitating a greater number of replacements to be made, and by the retardation of the development of the surviving young palms. In the present case this reduction is likely to correspond with the countervalue of two years of production from the young stand, obtained at the end of the economic life of the replanting. From the cumulative numbers of leaves produced, representing more or less the physiological age of the young palms, it can tentatively be deduced that the benefits of maintaining the old stand completely or partially for a varying number of years will be reduced by the countervalue of the following production from the young palms (*Table 16*). It will depend on the production of the old stand and the number of years it is partly or completely retained, and the production which may be expected from the young palms, which replanting technique can be recommended in any particular case.

Table 16. Estimated Reduction in Months of Full Production from the Young Palms as a Consequence of Retaining the Old Stand for Various Periods of Time

Time (months) old stand retained	*Reduction in months of production young palms*	
	No felling	*50 per cent felling*
6	3	1·5
12	6	3
18	10	5
24	13	6·5
30	16	8
36	19	9·5

The benefits of fertilizing will largely depend on the fertility status of the replanted area. It is evident from the results obtained in this experiment, that the benefits of fertilizing are limited as long as the old stand is completely retained, but very important if the old stand is removed previous to replanting. It seems likely that the effect of fertilizing will be intermediate if the old stand is partially retained, because of the reduction of root competition and the improved light conditions for the young stand.

In the present case the benefits of fertilizing were highly reduced by an unforeseen minor element deficiency in the soil, which could only be corrected at the end of the period of observations covered by this report, after it was shown that Little Leaf disease is caused by boron deficiency.

We have, therefore, good reason to believe that the benefits of fertilizing would have been much greater if this disease could have been prevented in due time. It is suggested from the cumulative number of male flowers, on the non-felled fertilized plots which did not suffer seriously from Little Leaf disease in the period considered, and the same data for the female inflorescences and bunches, that a correct fertilizer formula is likely to affect the cumulative productions of the young palms in such a way, that 1–2 years of full production are gained over a fixed number of years after replanting.

The results obtained so far do not yet allow an evaluation of the effect of felling and fertilizing on the future production per hectare per annum from the young palms. It should be borne in mind, however, that non-felling increases the mortality and therefore the need for replacements, which is likely to reduce the maximum level of future productivity to some extent. Fertilizing, on the other hand, is likely to improve considerably the level of the future productions in the present case, in view of the poor nutrient status of the soil. This does not necessarily mean, however, that fertilizers will always be profitable for replanting, as the benefits from fertilizing depend highly on the nutrient conditions of the soil.

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Some Aspects of the Nutrition of Tea in Southern India

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INTRODUCTION

The tea plant (*Camellia sinensis*) grown in Southern India is usually of the variety *assamica* or the hybrid of the varieties *assamica* and *sinensis*. Left to itself, tea will grow into a smallish tree about 25 ft. high, but under cultivation it is maintained in the form of a compact bush by spacing (plant populations in general being about 3,000 bushes per acre), and by vigorous pruning. Tea is manufactured from the terminal bud and the first two or three leaves of the tender shoots of these bushes, and in Southern India harvesting the flush, ' plucking ' as it is termed, continues throughout the year at intervals varying from seven to fourteen days, depending upon the rate of growth. Pruning is carried out at regular intervals ranging from two to seven years, the length of the pruning cycle depending upon the various environmental factors controlling the growth rate, the major ones being climate and elevation. The severity of pruning varies with estate practice, but the normal is now to cut back the bushes to about 20 in. above ground level and allow the re-growth of about 8 in. of maintenance foliage above the pruning cut before plucking is started. Since the appearance of Blister Blight disease in Southern India in 1946 there has been a marked tendency for pruning to become less severe, for more maintenance foliage to be left and for pruning cycles to be extended.

In 1940 the Scientific Department of the United Planters' Association of Southern India started a factorial experiment to assess the response of tea to applications of three levels of nitrogen, phosphoric acid and potassium. The experiment was laid out at the UPASI Experiment Station in the Nilgiri-Wynaad District on a soil of gneissic origin, which may be described as a latosol of very high clay and silt content. The area used for the experiment consisted of tea planted in 1927 and 1928 with a mixed population of hybrid and *assamica* varieties lightly shaded with *Erythrina lithosperma*. The plots were set out in factorial design, plot size being 15 × 15 (225) bushes. Although at the time of setting out the experiment no actual bush census was taken, it may be assumed that in all cases plots contained at least 220 bushes.

Throughout the course of the experiment nitrogen was applied at 40 and 80 lb. per acre in the form of sulphate of ammonia, phosphoric acid at 20 and 40 lb. per acre as superphosphate, and potassium at 20 and 40 lb. per acre as muriate of potash.

EXPERIMENTAL RESULTS

In the case of tea there is a marked pattern of crop distribution throughout the pruning cycle, and in studying fertilizer responses the important basis

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of comparison is the pruning cycle and not individual years. For this experiment the response of tea to the individual nutrient elements, cycle by cycle, is given in *Table 1* and for the sake of convenience this information is presented in the form of a graph (*Figure 1*), which is expressed as mean yield per plot in terms of pounds of green leaf for four pruning cycles. The results are very much in accordance with those obtained in the course of a similar experiment in Ceylon (Eden, 1949 and 1952; Portsmouth, 1950 and 1953).

Table 1. Average Crop Response to Individual Nutrients. Lb. per Acre Made Tea

	N_0	N_{40}	N_{80}	P_0	P_{20}	P_{40}	K_0	K_{20}	K_{40}	Sig. Diff. 5%	Sig. Diff. 1%
Cycle I 1940–43	868·0	963·3	1125·6	937·1	1019·4	1000·0	1011·7	930·3	1014·6	111·1	168·3
Cycle II 1943–46	906·7	1068·7	1356·3	1040·6	1137·1	1154·0	1057·2	1073·3	1201·2	197·1	298·6
Cycle III 1946–49	902·3	957·4	1272·7	998·8	1065·0	1108·4	827·4	1057·4	1253·6	263·4	399·1
Cycle IV 1949–52	984·0	1047·4	1474·1	1156·8	1159·6	1189·1	754·7	1253·0	1487·8	333·7	505·5

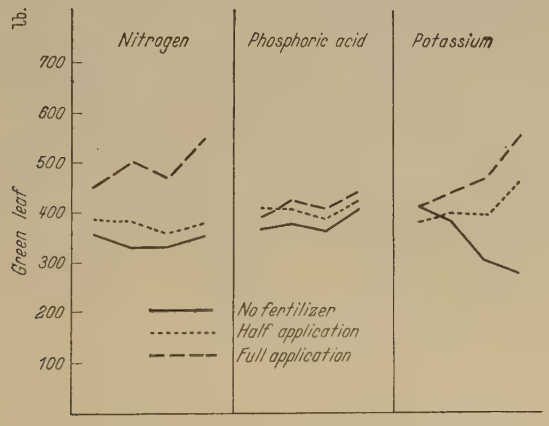


Figure 1. Mean yield of tea. Four 3-year pruning cycles

As can be seen from the graph, applications of nitrogen at 40 lb. per acre have had little effect upon yield, though 80 lb. per acre has provided a highly significant response. Phosphoric acid at either the 20 or 40 lb. level has had no significant effect on crop production, but in the case of potassium the results are more complex. For the first eight years of the experiment no response to potassium was observed, but thereafter the importance of this nutrient became manifest and in the latter part of the experiment it became, in fact, the dominating feature. During the third cycle, tea receiving no potassium declined significantly while that to which either 20 or 40 lb. of potash per acre was being applied maintained its previous level of cropping. In the fourth cycle a decline on the part of the control plots was still to be observed, while the tea receiving both levels of application of potash increased significantly in yield, although the difference in crop between K_{20} and K_{40} plots falls just short of statistical significance.

Further examination of the figures in order to determine the extent of nutrient interaction proved puzzling. In view of the total lack of response to phosphoric acid it was unlikely that there would be any significant interaction between it and either of the other nutrients, and this proved to be so. In the case of potassium and nitrogen, however, the yield figures suggested that there should be a significant interaction between these two nutrients. The mean yields per plot for the four cycles in respect of the three levels of potassium in conjunction with the three levels of nitrogen are shown in *Figure 2* and suggest strongly that there is a positive NK interaction. However, if the linear and quadratic components for N, K and NK are examined cycle by cycle, none of the components of interaction appears as significant, with the exception of cycle 1940 to 1943. The reason for the failure of the statistical analyses of the higher order interactions to indicate any significance is probably due in part to the design of the experiment, which is not sufficiently sensitive, and perhaps even more to the fact that in the case of the K_0 plots, a significant reduction in the number of bushes in each plot has complicated the results and increased the error.

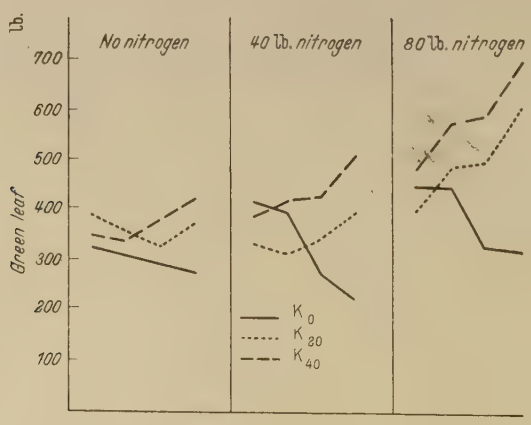


Figure 2. Nitrogen/potassium interaction mean: treatment yields of four cycles

If the mean plot yields for the nine interactions for the whole 12 years of the experiment are taken and the figures set out in diagrammatic form, (*Figure 3*) the results show that, in the main, the interactions are highly significant and in particular the response to the higher dose of nitrogen is much greater in the presence of even the 20 lb. application of potassium. In the absence of potassium the increase in yield of the tea to the 80 lb. application of nitrogen is only 28 per cent of the initial yield, but in the presence of K_{20} and K_{40} the increases are 40 per cent and 55 per cent respectively.

The reduction in bush number mentioned earlier is the most striking feature of the experiment and the appearance of the various plots, especially those which have not received any application of potassium, is most striking. The bushes are thin and debilitated and instead of a full cover of tea there are a large number of vacant areas, from which dead bushes have been

removed. In every case the death of the bush has been due to physiological and not pathological reasons.

The average number of bushes in each of the major treatments, at the end of the third pruning cycle in November 1949, at the beginning of plucking and at the end of the fourth pruning cycle, in May 1950 and November 1952 respectively and at the commencement of plucking in April 1953, are shown in *Table 2.*

Table 2. Average Number of Bushes per Plot

	N_0	N_{40}	N_{80}	K_0	K_{20}	K_{40}
November 1949	215	210	217	208	214	220
May 1950	207	191	206	178	207	218
November 1952	199	182	199	161	200	217
April 1953	183	154	176	122	177	217

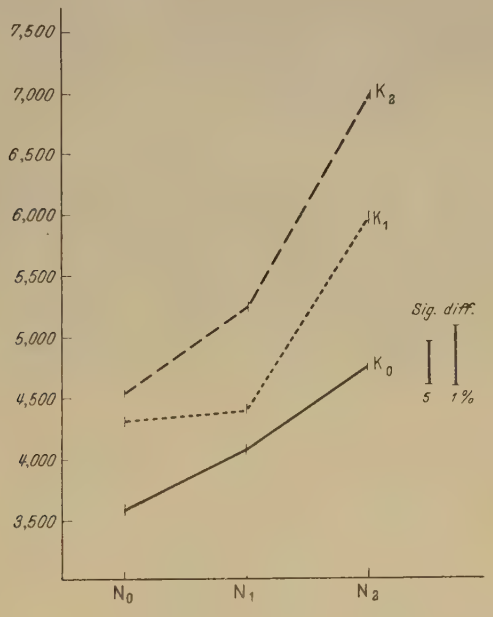


Figure 3. Interaction of N *and* K. *Treatment yields in lb. green leaf. 1940–52*

It is quite clear from these figures the extent to which reduction in plant population has occurred in all treatments except the K_{40} plots. This treatment effect upon plant population is most pronounced at the time of recovery from pruning, for it is at this period that the greatest number of bush casualties occur. In the case of K_0 there had been a reduction in plant population by only 7·5 per cent between 1940 and November 1949, but after pruning in 1949 another 13·3 per cent of the bushes failed to recover. In contrast, the K_{40} plots had suffered only 2·2 per cent casualties up to 1949 and after pruning only 0·9 per cent of the bushes failed to recover. This trend is even more noticeable on the occasion of the November 1952

prune, when 17·3 per cent bushes of the K_0 bushes failed to recover and in the case of the K_{40} plots there was no reduction in plant population at all. These data are reproduced in full in *Table 3*.

Table 3

	Per cent decrease in bush population					
	N_0	N_{40}	N_{80}	K_0	K_{20}	K_{40}
Nov. 1940/Nov. 1949 ..	4·4	6·6	3·5	7·5	5·0	2·2
After 1949 pruning	3·5	8·25	5·0	13·3	3·0	0·9
Pruning cycle IV 1949/52 ..	3·6	4·0	3·0	8·0	3·0	0·3
After 1952 pruning	7·1	12·4	10·2	17·3	10·2	0·0
Total reduction	18·6	31·25	21·7	46·1	21·2	3·4

If the figures of bush population for the nine interactions of N and K are extracted, they prove most interesting. *Figure 4* gives this information and demonstrates quite clearly that, in the absence of potassium, applications of nitrogen have had a significant effect upon reducing plant population, which reduction becomes less apparent in the presence of K_{20} and disappears entirely in the case of K_{40}.

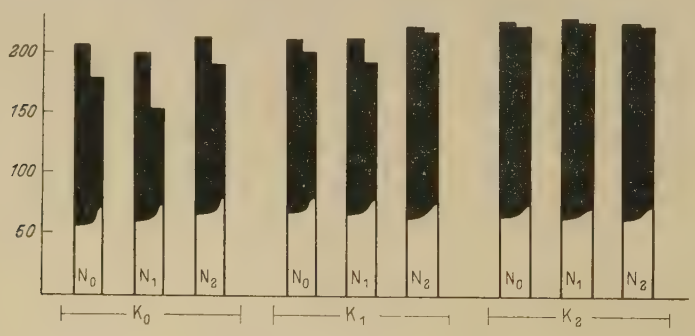


Figure 4. Mean number of bushes per plot. Nov. 1949 and Nov. 1952

The final series of data refer to the effects of treatments on the cropping capacity of the individual bushes. The mean annual yields per bush for the four pruning cycles, in the case of major treatments, are:

Table 4. Average Annual Yield per Bush (lb./green leaf)

	N_0	N_{40}	N_{80}	K_0	K_{20}	K_{40}
Cycle I 1940–43	1·624	1·845	2·08	1·955	1·75	1·807
Cycle II 1943–46	1·56	1·88	2·314	1·88	1·853	2·022
Cycle III 1946–49	1·566	1·689	2·17	1·47	1·836	2·156
Cycle IV 1949–52	1·795	2·085	2·70	1·669	2·283	2·527

These data are positively correlated with the crop per acre figures given in *Table 1*. To consider only the fourth pruning cycle, treatment N_{80} has significantly increased the yield per bush over treatment N_0, as treatments

K_{20} and K_{40} have over treatment K_0; but the differences between treatments N_0 and N_{40} and K_{20} and K_{40} fall short of significance. These figures can, however, be examined in the light of the nitrogen/potassium interactions, details of which, for the fourth pruning cycle, are given in *Figure 5*.

In the absence of potassium, increasing applications of nitrogen have no significant effect on bush yield. Where 20 lb. of potassium is present, however, the higher dosage of nitrogen has significantly increased yield over the no nitrogen treatment, and in the presence of 40 lb. of potassium, an addition of 80 lb. of nitrogen per acre has increased the yield significantly over both N_0 and N_{40} treatments.

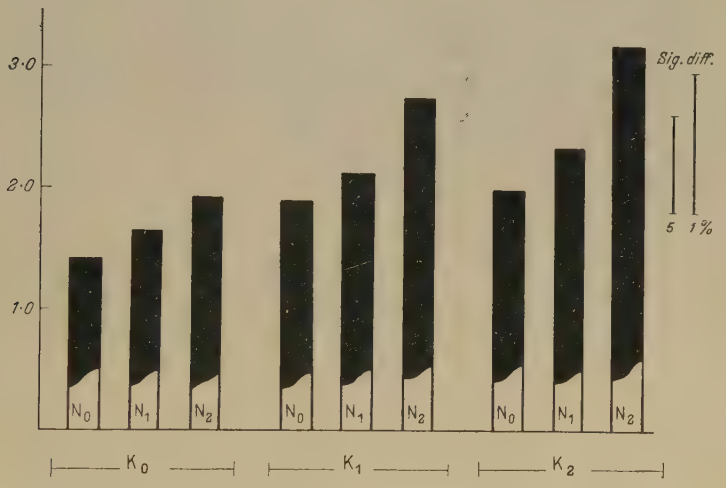


Figure 5. Mean bush yield in lb. green leaf per annum. Cycle IV 1949–52

DISCUSSION

As a result of 12 years of investigation, it has been shown that application of 80 lb. of nitrogen per acre and 20 and 40 lb. of potassium per acre have all had a significant effect upon crop yields. The experiment has failed to disclose any statistically significant interaction between nitrogen and potassium during the later stages, in spite of a strong indication that such an interaction might exist. However, if figures are extracted from the mass of experimental data and analysed statistically, leaving out of account the presence or absence of phosphoric acid which has not produced any observable response, there is statistical support for the postulation of a positive NK interaction. This is brought out by the data presented in *Figure 3*.

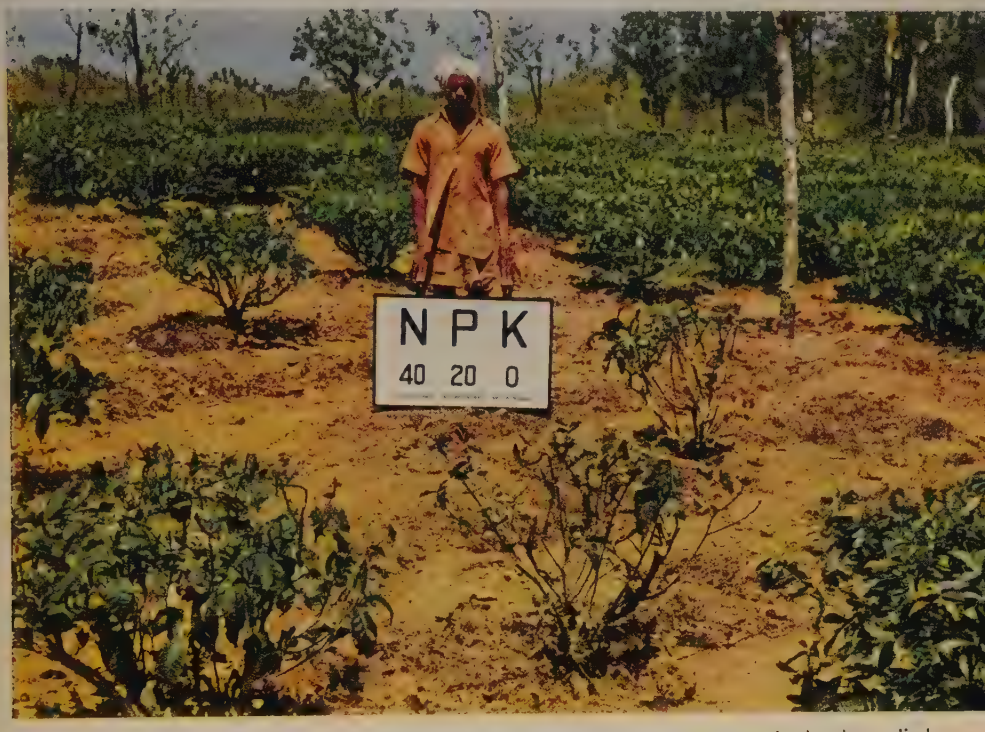
Yield per unit area is dependent upon the interplay of two factors, plant density and individual plant yield. The overall absence of potassium has had a marked effect on reducing plant population and only in the case of the K_{40} treatment has the bush density been maintained at its original level. In particular, applications of nitrogen, in the absence of potassium, have significantly reduced plant populations, apparently as a result of

potassium-starved plants being less able to withstand and recover from pruning operations. This indicates that nitrogen applications, without added potassium, have had an adverse effect upon the carbohydrate reserves of the tea bush, as was discovered when a series of analyses were conducted as part of the investigations into the 'Defoliation' of tea in 1948/50. (DE JONG, 1950 and JAYARAMAN, 1950).

From 1947 onwards, tea in certain areas of South India, notably in the Nilgiri-Wynaad and Wynaad, suffered a considerable setback, large areas of tea defoliating and dying out. This decline was eventually ascribed to drought, the North-East Monsoon which is the main factor in this area having failed in 1947 and in subsequent years. This, combined with the introduction of the Blister Blight disease and changes in cultural practice made to offset these attacks, undoubtedly contributed to the decline, but there is no doubt that it was also accentuated by the widely practised policy of applying only nitrogenous manures to the tea in these areas. It is significant that most of the tea suffering decline was of varieties similar to those planted in the experimental area and planted at much the same time. It is also significant that widespread decline in these areas was noted at about the same time that the first signs of response to potassium applications became apparent in the experimental area.

In the case of the experiment, reduction in plant density has in some cases been accompanied by an increase in individual plant yield, though whether the increase is a treatment effect or the result of the natural plasticity of the bush responding to a decrease in plant density, it is difficult to assess. In the K_0 treatments, figures show that in the fourth pruning cycle a reduction of bush density has been accompanied by a fall in yield per bush, no doubt because the absence of potassium was a limiting factor in the case of the surviving bushes, while yields per bush in the N_{80} and K_{20} and K_{40} treatments are much higher than those recorded during the first pruning cycle. In this connection certain investigations carried out in 1947 by one of the authors (JAYARAMAN, 1947), are of interest. In these investigations the increases in yield of the various plots were examined to detect if they were a result of increases in size and weight of the individual plucking shoots or the increase in numbers of shoots. During this year—the first year of the third pruning cycle—the only manurial treatment which produced a statistically significant response was N_{80}, but when the counts and weights of plucking shoots per bush were recorded and the figures analysed, it was shown that the higher level of nitrogen and both levels of potassium had resulted in significantly higher numbers of shoots per bush, though there was no significant increase in shoot weight. From this it was concluded that increases in yield were due to the increase in the number of pluckable shoots and not to any increase in shoot weight. This conclusion was confirmed by records taken at pruning time, which showed that the amount of plant material removed in the form of prunings was significantly higher in the case of these treatments. Unfortunately, similar information is not available for any of the latter years of the experiment. On the basis of the available evidence, however, it can be postulated that applications of nitrogenous and potassic fertilizers increase the yield of tea by influencing the rate of shoot development rather than by increasing shoot size.

Experiment Station of the Scientific Department of the United Planters Association of Southern India



Without potash thin wood and poor foliage on surviving bushes; many bushes have died.

Complete manure with potash. Note that the bushes cover the ground completely. Adequate foliage, no vacan

SUMMARY

(1) Some of the results of a 12 year NPK manuring experiment at the UPASI Scientific Department Experiment Station are discussed.

(2) Nitrogen application at 80 lb. per acre has increased crop yield significantly.

(3) During the eighth year of the experiment and in subsequent years applications of potassium at both 20 and 40 lb. K_2O per acre have also had significant effects upon crop yield.

(4) In the absence of potassium there has been a marked reduction in the number of bushes per acre, due mainly to potassium-starved bushes being less able to withstand and recover from pruning.

(5) Indications of an interaction between N and K are not borne out by conventional methods of statistical analysis. This problem is discussed in some detail particularly in relation to the effect of these nutrients singly and in combination on plant density and crop production.

ACKNOWLEDGEMENTS

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Root Grafting of Coffee Seedlings

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Root grafting is commonly used in North America[1] for the grafting of apples and is practised in many other countries for the propagation of ornamentals which prove difficult to reproduce by other methods.

Very little root grafting has been done on coffee. The most recently known published work was carried out in Java during 1936[2] on *robusta* types. Portions of tap and lateral roots taken from six year old trees were used and described as ' of normal graft thickness '. No success was obtained from cleft or perfectly fitting whip grafts when planted in either glass-covered or open frames. In a further attempt the rootstocks were of the diameter of very young, not long germinated seedlings. Similar material was used for the scions. These grafts were also placed in frames, the unions being above ground. Some of the grafts were covered with glass tubes and others with paper cylinders. The grafts under glass produced 100 per cent unions, but those under paper were less successful.

The seedling root graft technique described in this paper was developed while investigating the possibility of rooting coffee cuttings in direct association with roots. For this purpose the rootstock was merely used as a ' nurse ' and, when the scion had rooted, the ' nurse ' root was broken away and the rooted scion replanted. Only the seedling root graft technique is described in this paper because it may be of interest to others engaged in this type of work.

Grafting Materials Used

Seedlings of from 12–24 months old were used for the rootstock. These were cut back to a point where the root diameter was compatible with that of the prepared scion. As was to be expected, the scions which were used for the 12 months old seedling rootstocks were composed of extremely soft tissue whereas those used on the older seedling rootstocks were of semi-ripe shoots. It would have been possible to use soft wood scions on the 24 months old rootstocks, but this would have meant cutting too far back into the roots to ensure complete union thereby discarding a great portion, if not all, of the valuable lateral root system and might possibly have had the result of retarding development.

No attempt was made to use fully matured scions; those used being two or three noded, soft and semi-ripe terminal shoots cut from vertical growths. Except for two small trials carried out with *Coffea excelsa* on *C. arabica* and *C. arabica* on *C. liberica*, the majority of the grafts consisted of *C. arabica* varieties (Harrar, Bourbon, Mysore, Guatemala, Rume Sudan, Amfillo and Red Leaves) on *C. arabica* rootstocks.

The type of graft used throughout was the cleft.

Preparation of the Rootstock

This was carried out by cutting horizontally through the root at a predetermined point comparable in diameter with that of the scion. It was observed, however, that provided one of the scion cambia was in contact with the cambium of the rootstock a successful union was possible. The cleft was made by carefully splitting downwards through the centre of the tap root with a very sharp knife.

Preparation of the Scion

This was performed by cutting a tapering wedge of $\frac{3}{4}$ in. to 1 in. in length through the second or third node below the first set of mature leaves, depending upon the diameter of the seedling rootstock being used.

Though the nodal cut did not appear to have any superiority over the internodal cut in relation to union, it was certainly much easier to cut at this point. The nodal region, being composed of much firmer tissue, enabled the scion to be prepared more easily and to be inserted into the cleft in the rootstock with far less chance of serious injury.

Generally speaking (except for *C. excelsa*) leafage did not require reduction but all axillary growths were removed. In one trial (see *Table 2*, No. 3) the terminal was completely removed to the first set of mature leaves.

The Graft

This was done by carefully opening the cleft in the stock to allow the entry of the scion which was then forced firmly but carefully downwards until well seated. Binding lightly with a raffia strand was carried out to ensure stability but it was observed that rootstocks often appeared capable of securely gripping the scions without the need for binding.

Planting and After-Treatment

Planting was carried out in closed glass-covered propagators which were shaded with hessian suspended on poles at a height of approximately 6 ft. above the frames.

The compost within the propagators consisted of a 1:1 mixture of decomposed coffee hullings and sand. The compost was about 1 ft. deep in the frame lying over broken stones which served to facilitate internal drainage. This depth was sufficient to allow the graft union to be buried just below the soil surface.

The planting depth is likely to be important as there was a slight tendency, when grafts were left in the frame over a long period, for the scions to produce roots if planted too deeply.

Grafts were watered following planting and from then onwards were mist sprayed daily with an ' Eclipse ' hand syringe to maintain humidity.

Union was complete in a month from the date of insertion but though it is believed that safe transference from the propagator would have been possible, the grafts were held in the frame for a further two months, by which time both root and scion were making growth. In one trial the grafts were held in the frame for a total of six months (see *Table 2*) to study the rooting potential of the scion. The grafts were potted up in banana pots on removal from the frame and were then placed in a glass covered hardening-off

frame where they remained for 14 days. For the first five days the frame was kept closed by which time the plants had recovered from the shock of transplanting and the frame-light was thereafter gradually raised to admit air, at two-day intervals, until fully open.

With the completion of the hardening-off process, the established grafts were removed to a shaded place where they remained until required for planting out. Planting was possible two months after being placed in the open, making a period of four-and-a-half months between grafting and readiness for planting in the field.

(Photograph by W. R. Ingram)

Figure 1. (a) Showing point at which rootstock is cut. (b) The prepared graft less raffia binding. (c) Shows union 10 months after making the graft. Note restriction of tap root as a result of being retained too long in a pot

Grafts left for long periods in banana pots, even under heavy shade, showed signs of stress. Cessation of growth occurred especially during the dry, hot season when the soil in the pots became more or less baked, making water penetration almost impossible. Moreover, banana pots quickly decay with regular watering or during the rainy season, with subsequent exposure of the graft union and roots. Root restriction also resulted when the pots were placed on a hardened soil surface (see *Figure 1* (*c*)).

Hormones

Seradix B. No. 1 was the only hormone tested. This was used in an attempt to determine whether or not the process of union could be accelerated

and also if rooting of the scion could be more readily stimulated. Though the hormone did not appear to accelerate union there was some indication that rooting of the scion was stimulated (see *Table 1*).

Trials

Five trials composed of a total of 190 grafts were planted, one of which (see *Table 1, Trial IV*) was planted in the open in a completely shaded nursery bed. This trial resulted in a complete failure. The following tables show the results.

Table 1

Trials	*Date set*	*No. set*	*Per cent taken at one month*	*Remarks*
I	1-2-51	20	100·0	Stocks were 12 and 20 months old
II	8-3-51	25 controls 25 hormone treated*	100·0 100·0	One scion in the hormone treated group produced a single root after 3 months in the frame
III	9-5-51	30	97·5	All stocks 2 years old and composed of *C. arabica* varieties as rootstocks
IV	8-3-51	50	Nil	Failure was believed to have been due to over-watering and over-shading

* *Seradix B.* No. 1.

In *Trial V* different techniques were compared (see *Table 2*) and the graft unions were planted one inch deeper than in the previous four trials to determine whether the scions could be rooted more easily.

Table 2. (Trial V)

Date Set	No. 1	No. 2	No. 3	No. 4
No. Set	10	10	10	10
No. Takes	10	6	10	10

No. 1 Vertical planting.
No. 2 Planting slantwise.
No. 3 Vertical planting but terminal of scion removed to first set of mature leaves.
No. 4 Vertical planting but scion slightly larger in diameter than stock to permit one side of the scion to overhang the stock.

The first sign of scion rooting was recorded five months after planting on two grafts of the No. 1 group. These produced roots between the fifth and sixth months. Roots were also produced on three of the scions in No. 4 group at between five and six months, and No. 3 group produced roots on one out of the 10 grafts during the sixth month.

Grafts were transferred from the frame to pots six months after setting.

SUMMARY AND DISCUSSION

Root grafting of coffee seedlings by means of the cleft graft should prove to be a much superior method to the more orthodox stem technique. The problem of identifying rootstock suckers without the aid of marking the union when *C. arabica* is grafted on its own rootstock is eliminated.

A number of modifications to the frame technique with a view to simplifying the process might be attempted. These tests show that seedling rootstocks ranging from 12–24 months old can be used successfully, but as the time factor is of great importance, the 12 month old seedlings are to be preferred.

By careful preparation of the cuts in both rootstock and scion it should be possible to dispense with the necessity for binding the point of contact.

During the trial the grafts were kept in closed frames for three to six months, but this period is not considered necessary when graft factors only are being investigated. The reason for holding the grafts for such long periods was connected with studies on scion rooting. As the graft union was sufficiently complete in a month, it should be possible to move the grafts from the frame after one month.

(*Photograph by W. R. Ingram*)

Figure 2. (*a*) *A close-up of the graft union 20 months after grafting.* (*b*) *The complete plant*

Though hardening-off the plants was successful, the technique requires improvement due to loss of plants after hardening. Instead of potting up and placing the plants in the hardening-off frame, it might be better if this process were effected in the original propagating frame. This would be possible in view of the fact that union of the grafts is uniform. When

hardening-off is complete the plants may be transferred direct to shaded nursery beds, being left there until required for planting in the field. Such a technique would not only prevent a loss of plants but would result in a tremendous saving in labour and frame space.

For laboratory work, potting up is likely to be desired and in this case larger and more durable containers than banana pots should be used.

The chance of scions producing roots is very remote indeed. It was only as a result of special treatment aimed at stimulating scion rooting that roots were produced in these experiments.

Though the root graft technique with coffee seedlings has proved to be completely successful under straightforward conditions, *i.e.* in propagating frames, there was no indication of success in the open. It might yet be possible, with further investigation, to develop a technique for outdoor conditions. For all practical purposes a successful open air method is desirable.

The grafts planted in the open were made during the long, hot dry season and consequently the nursery beds were kept saturated with water. As damping-off of the scions was considered to be the cause of failure it is possible that a measure of success could have been achieved had more consideration been given to control of moisture requirements and to external climatic conditions. Further investigations should be designed to determine the conditions most suitable for grafting in the open.

The use of more mature scions for outdoor working might also be investigated.

A coffee seedling in the Ruiru district of Kenya is normally ready for planting in the field at 18 months from the date of sowing the seed. A root graft grown under favourable conditions on a 12 month old rootstock is ready for the field in 16 months. Under less favourable conditions a root graft should be ready for planting out at 18 months from the time the seed of the rootstock was sown.

In view of the ease with which the seedling root graft can be propagated the technique should prove of special value for investigating the influence of rootstocks and for transmission work.

(*Received August 1954*)

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Book Reviews

A PLAN TO INTENSIFY THE DEVELOPMENT OF AFRICAN AGRICULTURE IN KENYA

Compiled by R. J. M. Swynnerton. Govt. Printer, Nairobi, 1954. 75 *pp.* Sh. 1/50

The five-year plan compiled by Mr. Swynnerton, Assistant Director of Agriculture, is based upon schemes prepared by district and provincial teams and the headquarters of the departments concerned. A preliminary memorandum from the Member for Agriculture and Natural Resources states that it is proposed to apply to the United Kingdom Government for an interest-free loan of five million pounds for its implementation; but part of this sum will be absorbed in the fulfilment of schemes planned earlier and now integrated into the larger proposals.

The main feature of the plan is an immense development in the cultivation of cash crops, namely coffee, pyrethrum, tea, pineapples, and sugar cane. Much less stress is laid upon food crops, though some increase in maize, pulses, rice, and horticultural crops is envisaged. On the livestock side, the provision of improved breeding stock from Veterinary Department centres will be greatly stepped up. The general means proposed to achieve these ends include: survey and registration of land holdings, an enlarged European and African agricultural staff, provision of loans to farmers, a series of cash crop boards on the Tanganyika model to control development and marketing, and improvement of land by irrigation, water supplies, and swamp reclamation.

It would be easy to criticize this plan in detail, and above all to ask what guarantee there is that the incentives proposed will induce the African to undertake development at the rate expected ? But such criticism is not very helpful; the authorities in Kenya are probably themselves more acutely aware of the weak points in the plan than anyone else. Problems are not always completely soluble, and the agrarian problems of Kenya fall more into the insoluble class than most. Here is an honest and necessary attempt to face some of the most urgent of them; and the most helpful attitude for the outside spectator is to give what encouragement he can from the sidelines in the hope that at least some measure of the improvements proposed can be brought about.—G.B.M.

PLANT LIFE IN MALAYA

R. E. Holttum. Longmans Green & Co., 1954. viii + 254 *pp.* (illus.) 18*s*

Professor Holttum has distilled thirty years of observation and a wide learning, unobtrusively displayed, into a delightful introduction to the plant life of Malaya. With the author as guide, philosopher and friend, the reader is made to feel that he has ' got inside the skin ' of the evergreen forest

community of that seasonless country, with its concomitant parasites and saprophytes, and even its ants.

The book is designed to appeal to Malayan residents, more particularly in the upper classes of schools and the lower ones of the university—if they can afford its price ! It is not designed for the agriculturist, who will nevertheless find some thought-provoking observations, particularly in the chapter on yams and other tropical root crops. What no agriculturist can be ungrateful for is the existence of a book which may turn some students' minds towards the plant sciences and so help to create the indispensable reservoir from which agricultural staff must be drawn. There ought to be many more books of this kind in tropical countries.—G.B.M.

AVIAN PHYSIOLOGY

P. D. Sturkie. Comstock Publishing Associates. Ithaca, New York, 1954. 443 *pp.*, 77 illus. U.S. $6·00

Dr. Paul Sturkie, Professor of Poultry Physiology at Rutgers University has published the first book devoted to the physiology of birds, the emphasis being on domestic types such as the chicken, the duck and the pigeon. The twenty-one chapters encompass the field of avian physiology in a most readable manner. The book includes many instructive diagrams and tables, which should be invaluable to both the student and teacher of physiology.

As far as the reviewer is aware, Dr. Sturkie holds the only chair in the much neglected field of avian physiology. Like all workers in new fields he has had the difficult task of garnering what information there is in order to direct a programme of teaching and research. Valuable though the reference list at the end of each chapter is, later editions of what may well become a classic text will probably be more comprehensive.

In these days of expensive books, ' Avian Physiology ' can be recommended without reserve to students and teachers of physiology, whether they be workers in the mammalian, avian or human spheres. To agricultural and veterinary students this text will provide a valuable library reference.—J.R.H.

METHODS OF SURVEYING AND MEASURING VEGETATION

Dorothy Brown. Commonwealth Bureau of Pastures and Field Crops, Bulletin 42, 1954. 223 *pp.*, 45 illus. *Shs.* 35

Those concerned with agricultural development in the tropics have for a number of years been paying increasing attention to the need for grassland improvement in all its aspects. For such, the publication of this book, issuing from the Commonwealth Bureau of Pastures and Field Crops, is a welcome event; not that it contains more than brief references to work done in tropical lands, for indeed very little of the type of work which forms the subject matter of the book has been as yet undertaken in the tropical field, but for the reason that here in compact and readable form is an account of the methods which have been used and proved in many parts of the world for the study of the economic potentialities of vegetation, based on an ecological approach, with the main emphasis on grazing lands of all types.

The trained and experienced worker will find in the book a wealth of information as to methods and techniques used for the assessment of grassland potentialities, productivity and utilization by workers throughout the world. Equally, the book will be of value to the student and to the novice, for there is a clear and logical build-up, for example, from the theory of sampling and sampling apparatus, through vegetation analyses and assessment of productivity to the ultimate goal of optimum utilization.

The book is notably well produced and excellently documented. Its preparation stands as a tribute to the industry of the author and its publication is one more example of the value of the work of Commonwealth Agricultural Bureaux.—A.B.K.

A CRITICAL REVIEW OF THE WORLD LITERATURE ON THE LEPIDOPTEROUS STALK BORERS OF TROPICAL GRAMINACEOUS CROPS

W. F. Jepson. Commonwealth Institute of Entomology, London, 1954. vi + 127 *pp.* 15*s*

Since it is not easy to write a critical review of a critical review, it is fortunate that there are very few grounds for criticism apparent in this publication, which will be invaluable to every entomologist concerned with practical control measures against these unobtrusive but serious pests. The author has, wisely, not attempted a comprehensive review of everything that has been written about stalk borers but has used his own wide knowledge of the subject to discriminate between the grain and the chaff. Even so, the list of references contains over 450 titles. The crops dealt with are maize, rice, the sorghums and millet, and sugar cane; with two exceptions the pests are all members of the two families Pyralidae and Agrotidae. Every aspect of the borer problem is covered; systematics, bionomics, population estimation and assessment of damage, natural enemies, and cultural, biological and chemical methods of control. In the last few pages gaps in existing knowledge are briefly indicated and suggestions made for further research.

One small criticism. Surely it is time that the irritating mock-modest use of ' the writer ' in preference to the personal pronoun, which has been condemned in nearly all recent books and pamphlets on the correct writing of scientific and technical English, should be finally abandoned ?—T.W.K.

CONSIDERATIONS AND PROCEDURES FOR THE SUCCESSFUL INTRODUCTION OF FARM MECHANIZATION

Prepared by Cornelius Davies. F.A.O. Development Paper No. 44, Rome, June 1954. 36 *pp.* $0·50 or 2*s* 6*d*

' The purpose of this paper is to emphasize and illustrate the type of careful thought, advance planning and provision of adequate services and skills that are essential if efforts to mechanize farming are to be successful '—and it achieves just that. It is easy to read and is phrased for the layman, yet not condescendingly so. A short discourse to be read by Ministers, and by administrators as well as agriculturists, but one that the enthusiast will not understand.—J.E.M.

VEGETATION AND WATERSHED MANAGEMENT

E. A. Colman. Ronald Press Co., New York, 1953. xv + 412 *pp.*, illus. 56*s*

The author's material relates solely to the United States, and he is himself a member of the forest service; but there is much that tropical agriculturists can learn from the book. Soil and water conservation problems have been studied longer and more intensively in the United States than in the tropics; or, to put it another way, conservationists have begun to set their targets higher there than we are yet able to do. There are many sections in the book from which we can all learn: on the control of silt in reservoirs, the influence of riparian vegetation on stream flow, and the effect of grass-burning on water yield from a watershed, for example.

On the other hand, the author's treatment of some aspects is disappointing; after a bald recital of much experimental work, he does little to evaluate the worth of the different experiments and often comes to no conclusions. Such is his handling, in Chapter 11, of the classic and controversial question as to whether watersheds can be as well protected by a suitable grass cover as by forest. In another instance, the reader is told that contour row cropping, as compared with rows down the slope, may reduce run-off by anything from 12 to 99 per cent; but he is given no clue as to where and why these differences occur.

The book is one which all soil conservation officers could read with profit, but will not necessarily need to keep by them for reference.—G.B.M.

MICRO-ELEMENT NUTRITION OF PLANTS

K. N. Lal and M. S. Subba Rao. Banaras Hindu University Press, Banaras 5, India, 1954. 246 *pp.* *Rs.* 20

The authors in their preface say that an attempt is made in this book to present a comparative account of the effects of several micro-elements on various aspects of the physiology of economic plants. Relevant facts from over 1,000 contributions of different workers have been marshalled together.

Their attempt, however, has not been a success, in that the book is merely a hotch potch of snippets from the 1,000 papers with little or no attempt to sort the wheat from the chaff.

The impression is given that the essential micro-elements are things apart from the plant rather than essential components of the healthy protoplasmic complex. Thus ' with improvement in technique, the utility of micro-elements became important '. No clear distinction is drawn between the micro-elements so far shown to be essential and the other elements which may occur in plants but have not yet passed Arnon's criteria of essentiality.

Bald statements like—' Rubidium sulphate is neither beneficial nor harmful to barley, oat, pea and bean '. ' Mercury is used to control potato scab at the risk of reduction of crop.' ' In sugar-cane manganese at 1 p.p.m. improves height '—mean little. Nor is the author's original work, as quoted, very convincing.

This book may be described as a summary of summaries and even its value as a source of references would have been improved if these had been given alphabetically in an appendix rather than scattered at the end of each chapter.—D.B.M.

FOREST ENTOMOLOGY IN HAWAII

Otto H. Swezey. Bernice P. Bishop Museum, Honolulu, 1954. ix + 266 *pp.*, 32 figures. $4·00

The title of this book is somewhat misleading. It does not, like most works on forest entomology, purport to describe the principal insect pests of forest trees and suggest control measures for them. In Hawaii, although many species of insects are associated with most species of trees, a balance is as a rule maintained in the natural forest and it is seldom that any serious damage results. The scope of the book is more accurately indicated by its sub-title: 'An annotated check-list of the insect faunas of the various components of the Hawaiian forests'. The insects, most of which are in no sense pests, are listed under their recorded host plants, which include ferns, grasses and other plants as well as forest trees. Predacious insects as well as parasites are also mentioned. Those species that are believed to be specific to a given host-plant are indicated by an asterisk, but since many are more or less general feeders it is inevitable that their names should be repeated under numerous plant species. Hawaii possesses a unique and extremely interesting endemic fauna, and this book will be a valuable work of reference for entomologists, not only those concerned with forestry, working in the Hawaiian archipelago. But it is not a treatise on forest entomology as usually understood.—T.W.K.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

A Report on Cacao Research, 1953. 10*s* 6*d*

Reprints are available, at varying prices, of articles in the Cacao Research Reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao (1945–1951 Report)—Price 5*s* plus postage.

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

Volume I Ranunculaceae to Araliaceae complete in eight parts and index. 26*s* 6*d*

Volume II Part 1. Rubiales. 2*s*
Part 2. Asterales to Primulales. 3*s* 6*d*
Part 3. Ebenales to Polemoniales (in part). 5*s*
Part 4. Polemoniales (in part). 5*s*
Part 5. Scrophulariaceae to Acanthaceae, in the press.
Further parts are in preparation.

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

Editorial

I.C.T.A. Reunion in London

In response to popular request the annual reunion in London of those associated with the Imperial College of Tropical Agriculture will take a different form this year. A reception and cocktail party will be held from 6 to 7.30 p.m. on Friday, 22 July, in the King Charles Suite, 4 Whitehall Court (above the West Indian Club). Tickets will be 17*s.* 6*d.* inclusive of canapés and drinks, and will be available from J. E. Mayne, The Clumps, Lower Bourne, Farnham, Surrey, England, after 20 June.

In previous years the reunion has taken the form of a dinner, but it is anticipated that members and their guests will prefer the new arrangement which should give them ample opportunity to meet and talk with their friends, and to go on to other forms of entertainment later in the evening.

Guests of either sex will be welcome, and a special invitation is extended to members of the Empire Cotton Growing Corporation whether they have attended the I.C.T.A. or not.

Small-Scale Farm Management Problems

A Paper presented at the Conference on Education and Small-scale Farming held in Trinidad, October 1954

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SMALL AND LARGE-SCALE FARMING

Although the subject of this paper is problems of small-scale farming, it is not intended by any means to imply that small-scale farming is all problems and no possibilities. On the contrary, I think small and medium-scale farming offers the greatest potential opportunity in tropical agriculture of the future. So far, the most progressive farming in the tropics has been built on the large-scale one-crop estate; but this organization has a host of managerial problems of its own, many of them becoming more and more unmanageable as communities develop beyond the stage of being merely suppliers of manual gang labour. Furthermore, I have little faith in what is a rather popular idea today that the problems of the small farmer can be solved overnight by co-operation; by the creation of an organization that is in a position to imitate large-scale estate methods. The future of the small farm is, to my mind, in small-scale farming and not in some hybrid organization that cannot exploit the advantages of smallness to the full. I think this future has great possibilities.

The fact is often overlooked that there are some very substantial economic advantages in small-scale agriculture; advantages that can result not only in an increase in output per acre (so important in our Caribbean area) but an increase in the overall average output per man and per unit of capital. These advantages arise from the possibility of far closer and more sustained managerial supervision of crops and livestock on a small farm. If a small farmer is convinced that he is making a good living from his land, he finds no hardship in catering for the personalities of each one of his few livestock, in observing and acting on the condition of every field crop at every period of the year. He can, in fact, undertake a system of production that involves far more personal observation to be successful than can a large estate. One of the most obvious ways in which tropical agriculture can progress is the evolution of more complicated and more skill-demanding systems of agriculture than can be developed on the large estate. A similar revolution occurred in England at the end of the eighteenth century when the enclosed sheep runs were superseded by the complicated and relatively small-scale farms founded on the four-course rotation. Estates, like sheep runs, will always have their place, but they should not be the only form of modern scientific farming if the maximum use is to be made of the economic resources available to agriculture.

Having made a profession of faith, let me turn to some of the problems. I am not sure that ' problems ' is quite the right word; they are much

more adverse conditions that have grown up as small farms have multiplied. The combination of these has usually led the small farmer into a position in which it is well nigh impossible for him to farm productively or even intelligently. His handicaps are often overwhelming and he continues farming not from choice but because it is the occupation of last and only resort.

Handicaps of the Small Farmer

Land—Small farmers in the Caribbean have usually to be content with the least accessible land. Typically it is infertile, rocky, mountainous, or swampy; sometimes all of these poor qualities combined ! The poor quality of his land is sometimes attributed entirely to historical causes. It is said that because West Indian agriculture developed under estate organization, the only land that became available to the small farmers was that which no planter thought good enough to form into an estate, or land on which estate agriculture did not survive. This is only part of the story. Even when small farmers are settled on good land they usually degrade it rapidly because of their other handicaps. Shifting cultivation is as much evidence of a poor farming system as inherently poor land. Considering the poor quality of the land, the average area available to an individual is usually insufficient to give full-time productive employment throughout the year.

Employment—Under-employment due to inadequate land is accentuated by the seasonal nature of production pursued by most farmers. The uneven seasonal labour requirements necessitate substantial wage earning away from the holding in slack seasons and very commonly the employment of paid labour on the farm at busy seasons. The part-time farmer who employs seasonal labour sacrifices the fundamental advantage of small-scale operation. He cannot exploit his theoretical advantage of close and keen management if he is not on his farm half the time and has to rely partly on paid employees.

Land Tenure—Land tenure is usually unsatisfactory in the Caribbean. Share cropping, which cannot be considered a satisfactory form of tenure for progressive agriculture, is only too common. Cash tenancies are usually contracted very unsatisfactorily; it is common that neither landlord nor tenant undertakes the responsibilities necessary to the satisfactory working of the system. Even when land is farmed freehold there appears to be little improvement in the standard of agriculture. Freehold, with so much sunk in the land, limits the amount of tenant capital available to work it, and appears to confer on many West Indians a sense of irresponsibility regarding land use.

Fragmentation—Fragmentation of small farms is common in the Caribbean because they are historically so recent. The majority of farmers today have had, during their own lifetime, to try to build up farms for themselves piece by piece. Rarely can they acquire new areas for expansion which are contiguous with their existing holdings. Fragmentation handicaps farming in respect of the tools and equipment that can be used, in the use of organic manure and other bulky by-products and in respect of larceny. The fragmented holding has also the fundamental handicap that the whole of the small farm cannot be constantly under the farmer's observation.

Marketing—There is a great contrast in the efficiency of marketing of the staple products for export and those for local consumption. The former is efficient and highly organized, the latter is most inefficient and disorganized. Although small farmers produce a large quantity of export products and benefit from the good marketing, there is potentially a number of locally consumed products suitable to small farmers which are at present produced only in small quantities because of the uncertainty and cost of marketing. The shortage and high prices for fresh vegetables and milk are two examples.

Crops—The large production of export crops by the small farmer is of itself worthy of mention. The relatively large dependence on a cash economy is a definite advantage in making small farmers in the Caribbean commercially minded. The preference for cash crops, however, aggravates the seasonal nature of employment on small farms, which from their products must try to imitate estates without possessing the advantage of a flexible labour supply.

Capital—The greatest handicap I leave to the last. Lack of capital is not primarily due to the lack of investment possibilities on a small farm. It is true that the possibilities are more restricted than on a large-scale, highly specialized estate, but the small farm is usually so deficient in capital that there should be a handsome return from the initial investment that can be made. The problem is not even one of absolute lack of capital but rather the unwillingness of farmers to make agricultural investments. Under-capitalized small farming is so universally accepted as the recognized system that surplus funds are usually invested in non-agricultural undertakings. This attitude is understandable when it is remembered what a poor living is made from most farms.

The lack of capital is exaggerated by the fact that the most urgent investments on a small farm are not power machinery or special buildings that from their attractive and solid appearance are obviously good value for money; they are in well cultivated and well fertilized crops, in systems of farming (probably including livestock) that will maintain and increase soil fertility. These are rather intangible and easily eroded assets. They can only be maintained by a good farming programme and a steady purpose. Any deterioration from an initially desirable system is a sacrifice of capital. Once sacrificed the farm will be less well equipped to re-accumulate the lost capital out of profits.

Capital and Labour Input

Most farmers attempt to remedy their lack of capital by increased application of labour. Capital, particularly, in its most liquid form, cash, is to most farmers the scarcest and most highly valued resource; labour, on the other hand, which appears to be always available is valued extremely low. Wherever we turn we can see evidence of the distorted valuation by small farmers of these two resources. For instance, maize is probably the most popular small farm crop; comparative costings at the Imperial College of Tropical Agriculture on similar farms showed that over a number of years maize gave a return of about 7cent per hour worked; properly planted sugar cane earned more than three times as much, averaging 23 cent an hour. Maize involves little or no cash outlay and gives a quick return, so it tends to be

over-produced. The next most popular small farm crop is probably sugar cane, but sugar cane cultivated at a lamentably low standard. Most of it is on what may be termed a ' cut and cash ' basis; cut the cane and receive a cash payment immediately. Cane is rarely replanted because that involves 18 months of expenditure before the first harvest is reaped. Small farmers rarely plant grass for livestock; why should they ? They will get no cash return and will save only their own time.

This over-application of labour and under-application of capital can lead to only one result, low standards of earnings per hour worked. Few small farmers even in Trinidad earn a net income of $500 a year from their farms, although many sugar estate *labourers* earn more than that.

Small Farm Possibilities

These handicaps make the detailed study of any existing small farming system about as rewarding as a similar study of a perpetual motion machine; neither has ever really worked nor is it likely to. However, none of these handicaps is theoretically insuperable; they have developed because the small farmer in the Caribbean is historically the last and poorest man in the race. For instance, the quality of peasant land can be rapidly improved if only the systems of farming practised made some attempt to conserve fertility. Land can be re-allocated so that fragmentation is no longer serious. There is enough land available for even these densely populated islands if it were only used for intensive crops intensively cultivated. Even the most difficult handicap, that of capital, is not insoluble. Capital is always forthcoming for any investment that is secure and earns good interest. Governments can create these conditions if they will assume the role of model and realistic landlord-capitalist; if they are prepared to advance money to small farmers on the strict condition that they practise certain clearly specified systems of farming. The initial experiments in a more desirable landlord-tenant relationship would no doubt have to be made on small, tightly organized land settlements each confined to one approved and proven system of farming. Administration would have to be more vigorous than is usual, and entirely free from political pressure. A few successful pioneer settlements would, however, be of immense educational value. The visible signs of prosperity of settlement tenants would impress their neighbours with the desirability of a well capitalized farming system. That is the first essential step towards better capitalized small farming.

But if these handicaps are corrected, is small farming fundamentally capable of yielding a good living ? Can the theoretical advantages of a small farm in respect of potentially good management outweigh the disadvantages in respect of specialized investment and lack of mechanical power ? The Peasant Investigation at the Imperial College was started with the object of answering this question. I need not burden you with an historical review of this investigation as a detailed report has already been published[1]. I can, however, give you the answers that the investigation has furnished and the main one is that there are definite possibilities in some systems of small farming.

Two manually operated farms out of the five types so far investigated have been carried to a definite conclusion. One is a dry-land arable farm

of three-and-a-half acres and the other an irrigated market garden of a little over one acre; each employs a man-woman unit of labour full time without the need for seasonal hired labour. Both these farms made net earnings of about $500 in the first years, but by modifying the organization and improving the management earnings have now been raised to $1,200 on the arable farm and $1,700 on the market garden. Here, then, are two systems that yield earnings high enough for the farmer and his family to be well fed, housed and clothed entirely from farming activities. For comparison, it may be pointed out that a junior clerk employed by the Government of Trinidad and Tobago commences his career at the basic salary of $960 a year.

The agricultural characteristics of farms that give relatively such high earnings are worth describing. On the arable farm the three enterprises, cane, yams and livestock form a completely interlocking combination; the yams are very responsive to pen manure which is applied exclusively to this crop; they repay a large application of total organic matter, the balance of which is supplied by cane trash. Yam crops on this holding are grown profitably with applications of about 25 tons of pen manure and 20 tons of cane trash per acre. Yams also demand thorough weeding and, when well established, smother the land and suppress noxious weeds. Yams are therefore a cleaning and fertility-building crop for the cane. The sugar cane makes a vital contribution to the livestock by supplying abundant fodder in the dry season when planted grass ceases growth. This supply of cane tops makes it possible to have ample fodder from only half an acre of Guatemala grass and for manufacturing manure at the rate of about 10 tons cured per cattle unit. These three enterprises in fact form a system that will maintain and build fertility; no less and no more enterprises are required.

On the market garden the rotation of fodder grass with crops is a sound and novel feature. Few market gardeners in Trinidad growing ordinary annual vegetables can crop continually, and a feature of most market garden areas is bush fallowing. Half or more of the potentially most productive land grows nothing usable. By growing a rotational grass the land is regenerated and the irrigation system is used in the dry season for grass production. The production of pen manure on the holding is an advantage few market gardeners enjoy, yet the amount from one cow permits application at the rate of 50 tons per acre for lettuce, and 10 tons per acre for the other crops.

LESSONS FROM UNIT HOLDINGS

What are the secrets of these two holdings that might indicate other possible systems for small farms ? There seem to be three. The first is that both these farms provide productive full-time employment throughout the year. There are no periods of idleness and no worker is required to work more than eight hours a day. Although the workers are wage-paid employees, earning rather less than if they were running their farms independently, it is gratifying to see the sense of stability, self-respect and self-reliance that they have developed. They now realize that steady, thorough work according to the well-planned programme is the key to the success of their farms and their own prosperity.

The second secret is that both farms exploit the advantages of smallness. The market garden is the most obvious. To be successful this farm demands a multitude of day to day observations and decisions. As experience accumulates, the productivity of the farm increases. For instance, in the early years the peasant produced at the rate of 5½ head of mature lettuce for every hour worked on this crop; he now produces 11 head per hour. Obviously a market garden pays for what may be termed micro-management.

A similar advantage has also been exploited on the arable farm. The peasant can pay much more detailed attention to his small area of sugar cane than is possible on a sugar estate; he has even more scope with his yams and livestock. In addition, the small area of this farm permits the transport of bulky material even with the crude equipment provided; the peasant can move grass and cane tops to his cow pen, manure and cane trash to his yam fields at comparatively little cost because such short distances are involved. The system of mixed farming is, in fact, a type which is economically possible on a small farm but impossible on a large estate.

The third secret of these holdings is that they demand heavy capitalization compared with normal peasants, and investment of a kind that is suitable to the small farm. The tenant capital (that is, excluding land, roads and water supply) required for the arable farm is about $3,000 and for the market garden $2,000; this represents tenant investment of $1,000 per acre or more. About half the capital is invested in crops and livestock, the other half in the tenant's house and buildings sited on the holding. None, of course, is invested in machinery or transport. Suitable investment at the rate of $1,000 to $1,500 per worker (exclusive of land) obviously makes satisfactory labour earnings a practical possibility.

OTHER POSSIBLE TYPES OF SMALL FARMS

With these characteristics in mind we can consider other small farm organizations which might be successful in the Caribbean. The two other unit farms at the College, which are most unfortunately now defunct, demonstrated how further capital can be invested with profit on cane-yams-livestock arable farms on light, free draining soils. One holding was equipped with a pair of oxen, implements and cart; the area cultivated had increased to about seven acres for the man-woman unit. Although high earnings had not yet been achieved the prospects were very good and in the long run considerably better than the manual holding. The other farm was an arable dairy growing three-quarters of an acre of yams, three-quarters of an acre cane and enough grass for three cattle units. As the quality of the livestock and the efficiency of yam production increased the prospects of this holding were also improving rapidly. Earnings at least as high as the market garden (*i.e.* $400 to $500 higher than the manual-arable) seemed ultimately sure from both these systems.

One unit in the College investigation was abandoned as being unsuitable on the area chosen; it was a specialized dairy farm. The conclusion was, however, that this type might be fully justified and might work well under other ecological conditions. The required conditions appeared to be poor, dry and probably hilly land with cheap irrigation water (probably a stream)

available on a small low-lying portion of it. The cattle could take full advantage of grazing in the wet season which could be augmented from the irrigated fodder patch in the dry. It was expected that a man-woman unit could manage a herd of from six to eight milking cows.

Certain other specialized livestock farms fulfil our requirements for small-scale farming. Pig or poultry keeping, mainly indoor, depends for success largely on careful management. The scientific standards of management required for these types are admittedly well above the present level of the small farmer but there is no reason, with experience and education, why local farmers could not master the intricacies. The reliance of these enterprises largely on purchased feed, the continuity of production throughout the year and the absence of much land to keep in order ensure full-time employment.

Other combinations of arable crops for mixed farming are quite possible in those Caribbean countries which are not suited to sugar cane. For instance, a unit farm is at present being developed in St. Vincent on arrowroot and other crops. The steep land of this holding is being kept under permanent grass for cattle fodder; it is planned to rotate the arrowroot slowly with the other root crops which will respond more to pen manure and be more amenable to clean weeding. Cotton with livestock and perhaps groundnuts might well prove another combination that is suitable and profitable for the small man.

Some orchard crops offer possibilities, the foremost probably being cocoa. The technique of cocoa growing has developed so much in recent years and is likely to develop so much more in the near future that large-scale, gang labour methods are becoming unsuitable. The small man, being in a position to increase management per tree, can give new clonal material the attention it will repay. A small cocoa farm of perhaps 10 acres on which 3 to 5 per cent is being replanted each year would provide quite satisfactory labour requirements and would at present prices yield a handsome return to the family. New methods of cocoa farming, incorporating perhaps cultivation and manuring, would also be very suitable for the small farm.

Citrus and coconuts are not so suitable because the former is too seasonal in its labour requirements and the latter is not responsive to high farming. Both these crops might, however, be used to provide cheap grassland for livestock farming.

CONCLUSION

Some of these suggestions may seem visionary to the practical man. They probably are when mounted on the background of present standards of small farming, but the present background must not be considered. If the small farmer in the Caribbean is forever to remain victim of the handicaps I have enumerated, he will remain a half-time, half-hearted scratcher of degraded land. He will have no hope of economic betterment, nor will the area as a whole. We *must* raise our sights to what a small farmer can do if reasonably situated as regards land and capital. The way to find out what is possible is, I am sure, by the unit farm technique developed at the Imperial College. The next step is to apply the systems that pass all tests on the units on well regulated and well disciplined settlements. These

settlements must in the end prove to the ordinary farmer that the systems practised are a sound and satisfactory means to making a living.

With so many Caribbean crops capable of giving high money output per acre, and with so many of them being cultivated in a most primitive way, there should be many possibilities for good management on a small farm to yield good returns. If only we can, by these means, succeed in combining the idle resources of labour in the Caribbean with capital wisely invested in productive farming systems, we can, I am sure, turn the area from a wilderness into a garden. I hazard that the greatest and potentially the most productive field for investment in the Caribbean is in the well managed small farm.

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Grain Storage Practices in India

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It is estimated that there are about two billion people in the world at present and that the world population is growing at the rate of 20 million persons per year. In our own country which has a population of 300 millions, the people are increasing by more than four millions a year. More than one-half of the people of the world do not get enough to eat and the increase in food production is not enough to keep pace with the ever-increasing population.

Cotton[1] mentions that about 25 million tons of grain are lost annually due to faulty methods of storage and suggests the need for efficient prevention and control of food infestation for conserving the world's food supply. In India alone a loss of about two million tons of grain is caused by insects and other factors. Increased food production can therefore be had not only by increasing the yield per acre, but also by adopting improved methods of storage and preventing wastage.

From time immemorial, different methods have been tried for conserving food grains, and the methods have varied depending on the prevalent conditions and other factors. In India, which is a tropical country, diverse practices have been followed in the past, but even today many of the traditional methods of storage are in vogue beside modern methods.

In this article the different storage practices, both ancient and modern, have been reviewed and their relative merits discussed.

UNDERGROUND STORAGE

Storage of grain in underground pits or simple dugouts is probably the most ancient method of storage. Hall and Hyde[2] considered the method helpful in preventing thefts. The fact that such pits used to be dug in the floors of human abodes supports this view. Even today, the underground method of storage is being followed in many parts of India either in its most primitive form or with modifications (silos). In other parts of the world also, modifications of this method appear to be in vogue.

Hall and Hyde[2] state that in such a method of storage damage to the grain is caused mainly by moisture, microbes and insects. They further mention that damage is minimum when the pits are located in sandy or high lying grounds. This may be the probable reason for the method being commonly adopted in the dry, arid regions of the world. Thus, in the dry sandy parts of Egypt[3] and other territories in Africa[4], storage of grains in underground pits is commonly followed. Likewise wheat, maize, barley, *jowar* (*Andropogon sorghum*) and *ragi* (*Eleusine coracana Gaertn.*) are stored in underground structures in the dry districts of India[5,6]. These structures hold 1,500–3,000 lb. of grain and keep it in good condition for three to five years[6]. Fletcher and Ghosh[5] report that the grain stored in

this manner develops mould and is therefore sold at cheaper rates. In spite of this, however, cultivators generally store their grains in pits. This is probably due to the universal appeal of the underground method of storage, the ease with which it can be adopted, the saving in space it effects, and the protection it affords to the grain from rats and insects.

Figure 1. Entrance to underground store
(By courtesy of the Concrete Association of India)

To prevent development of mould and make the underground method of storage suit even tracts that are not arid, suggestions have been offered. Doyére[7] showed that damage does not occur when the pits are lined with concrete and metal. However, concrete lining alone does not prevent the ingress of moisture and air[8]. Fletcher and Ghosh[5] state that damage due to mouldiness is minimum in the case of grains stored in pits lined with concrete. According to Hall and Hyde[2] considerable quantities of grain are stored in several parts of the world in metal-lined pits and keep well for five to seven years. Pingale[9] mentions that in the State of Bombay grains are stored in underground structures lined with husk and straw to prevent damage from moisture; it is surprising that such materials could be used to provide a water-tight layer. However, it has been shown that the presence of insects or microbes causes heating in the grain which results in the moisture from the grain settling on the walls of the pit[10]. When the pit is lined with straw and husk this moisture is absorbed, but in the case of a pit lined with metal or concrete the grain at the periphery absorbs the moisture

that settles on the concrete walls and is thus exposed to relatively more damage.

In the case of damage due to seepage of outside moisture, a metal lining for the underground pit gives sufficient protection to the grain, but when damage is caused by precipitation of the moisture produced from the stored grain, a lining of some suitable material which would either absorb the moisture or avoid its precipitation is indicated.

OTHER METHODS OF STORAGE

With the advance of civilization and progress in the field of engineering, man began to construct dwellings for himself and big warehouses for large-scale storage of grains. This resulted in a shift from the underground methods of storage to above-ground ones. When the quantity to be stored was large the grains were placed in heaps (*bulk storage*), but when the quantities were small, receptacles were commonly used (*receptacle storage*).

Bulk Storage

According to ATTIA[3] in Egypt the grains were stored in open spaces enclosed by barbed wire and earth or straw. Such structures are known as ' Shownas ' and the method followed is one of ' bulk storage '. YING-TOU MAO[11] mentions that bulk storage is commonly followed on Chinese farms. WILSON and GAY[12] report that at the ports in Australia, grain is stored in heaps in big sheds. In the coastal regions of India, paddy and some millets are stored in a similar fashion[9].

PINGALE and PATEL[6] have shown that in this type of storage, damage due to moisture plays a big part. They recommend a lining of dry husk or straw at the sides and bottom of the grain to prevent this. However, the damage caused by insects to grain stored in bulk is much less compared to that caused to grain stored in jute bags[12]. This is due to the heat produced in the grain bulk accumulating inside and restricting the insect activity to the periphery of the grain bulk[6]. It is further reported that disturbance of the grain bulk increases the insect activity in direct proportion to the quantity of heat caused to be removed. However, according to MUNRO[14] regular turning of the grain stored in heaps is necessary to avoid damage. This apparent contradiction might be due to the damage being caused not only by insects but also by microbes, in Munro's experiments. In fact, it has been shown that grain stored in bulk is susceptible to damage by microbes[15].

In bulk stores, microbes are likely to cause more damage than insects, but only grain with a moisture content of over 15 per cent is susceptible to microbial damage[16]. Therefore, grain for bulk storage must have as little moisture as possible. The success of bulk storage in India is due to the grains containing a moisture of 11–12 per cent.

Receptacle Storage

The receptacles used are of different sizes and are usually either jute bags, or bins made of earth, wood, bamboo, metal and cement.

Bin Storage

Bin storage is followed in many parts of the world. Ying-Tou Mao[11] reports that some of the producers in China store their grain in bins made

of earth or bamboo matting. In India, different types of earthen, wooden, bamboo, metal, cement and coir bins are used, the most modern being made of cement. The capacities of these bins have been reported to be 300–30,000 lb. of grain[4,6,17].

Damage to grains stored in bins is mainly due to insects and moisture[9,18]. Disturbance of the grain stored in bins results in heavier damage[19]. This explains the prevalent practice in our country of sealing the bins and leaving them undisturbed.

PARKIN[22] reported that when there was removal of heat the moisture in the grain tended to settle on the walls of the bin. Such a condition generally occurs in metal or cement bins exposed to diurnally varying temperature conditions. The precipitated moisture is absorbed by the grain in contact with the inner walls of the bin and this results in heavier damage. To offset this, Parkin[22] suggests blowing hot air inside the bins at intervals. KIRK, LING and OXLEY[20] suggest drying of grain prior to storage to protect it from damage. According to PINGALE[19] an earthen bin is suitable even for the storage of moist grain since it is a bad conductor of heat and allows the moisture produced inside to escape without the aid of any mechanical means. It is interesting to note that the report of the Planning Commission of India[23] also admits the value of traditional methods of storage including storage of grain in receptacles that are bad conductors of heat and allow egress of the moisture produced inside.

Modern methods of receptacle storage employ cement and metal bins. Cement bins of large size and huge capacity are used especially in America and Great Britain. Such bins are not air-tight and the grains stored in them are removed with the help of mechanical devices. According to the report of the Pest Infestation Laboratories[24] metal bins, especially those of aluminium, are being tested for possible large-scale use. It must be mentioned that cement or metal bins are rat-proof, moisture-proof and to some extent, insect-proof as well. Further, they are not fragile like earthen bins.

Jute Bags

Jute bags are extremely unsuitable for the storage of foodstuffs as they do not afford protection against pilferage, insects, rats and moisture[5,6,26]. However, considering the existing facilities in India for the handling of foodstuffs, whether in storage or during transit, a more economical receptacle cannot be had. Therefore, jute bags are, and will remain, a popular receptacle in India, at any rate for a long time. The bags vary in size, texture and weight and some of the more commonly used types are described by Parkin[22].

PINGALE[25] has reported a higher insect damage to grains stored in jute bags as compared to those stored in certain earthen bins. He further showed that these losses are not felt by the trade in India due to the seasons at which the storage and disposal of grains are carried out. Grain for storage is generally obtained during the dry months of the year and disposed of during the wet months. This results in the moisture gained by the grain during the wet months balancing the losses caused to the weight of the grain by insect damage.

As mentioned earlier, in spite of its draw-backs, the jute bag is extensively used for the storage of grains; hence efforts are being made to render it insect-proof[25].

RELATIVE MERITS

Stored grains are subject to theft and damage by rodents, insects and microbes. Therefore, the merit of any method of storage lies in the protection offered by it to the grain against these factors.

The different methods of storage described above could be broadly grouped under two heads; air-tight, and loose or non-air-tight storage. Storage in metal bins comes under the first category and storage in the other types of containers in the second.

In the air-tight method of storage it has been shown that carbon dioxide accumulates inside and tends to control microbes, insects, rodents and pilferage[2]. However, Oxley[16] points out that anaerobic microbes are active even under air-tight conditions and cause damage. According to Hyde[8] grains stored in air-tight, metal-lined bins develop a sour alcoholic smell. Provision of a sorptive layer to the bin may offset this.

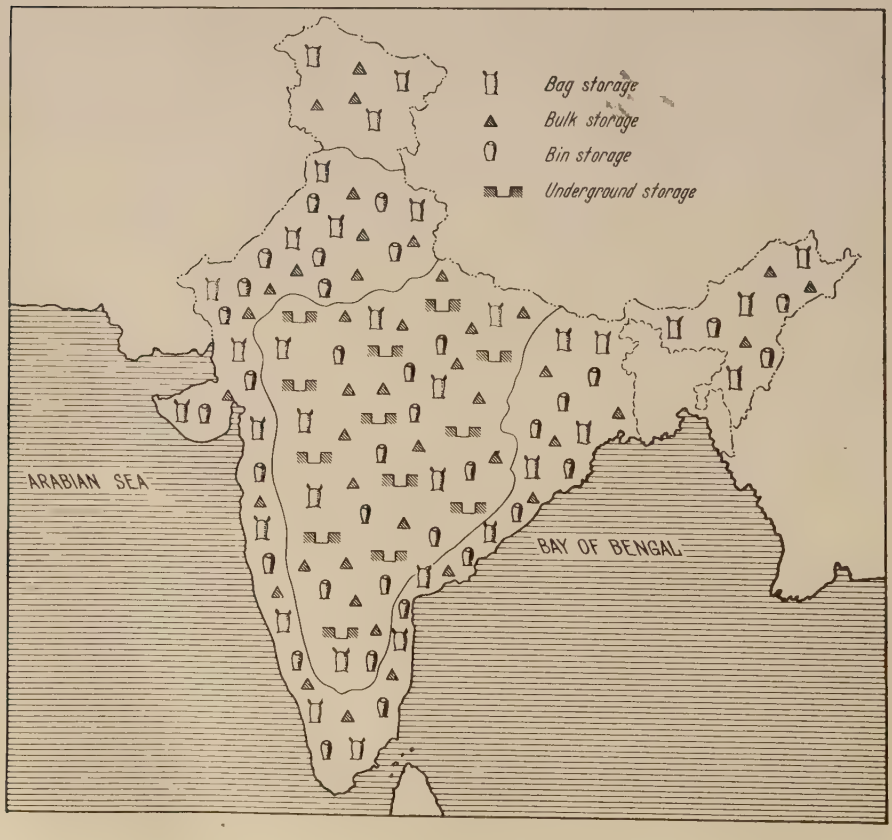

Figure 2. Map of India showing the different grain storage practices followed

In foreign countries the air-tight method of storage could be naturally followed on account of the high moisture content of the grain. In India, however, as the grain has a low moisture content at the time of storage, the method does not offer much promise.

The underground structures which do not have a metal lining have been shown to be non-air-tight[8]. Reports on the percolation of water into such structures seem to confirm this view[6]. However, according to Fletcher and Ghosh[5] many persons who have tried to steal grain from underground structures have been killed due to the accumulated carbon dioxide. It has been shown that underground stores constructed even in public places have remained safe. This is because thieves could gain access to the grain only after the stores had been kept open for 2–3 days. This suggests that the underground structures in India, though not air-tight, do not allow the carbon dioxide produced to escape. Further, the stored grain being dry, the percolation of moisture into the structure might have helped in the production of larger amounts of carbon dioxide.

Available information shows that in the non-air-tight method of storage, losses due to insects, microbes and other factors are minimized when the heat produced is allowed to accumulate and, at the same time, the moisture given out is absorbed. A number of receptacles have been used in the non-air-tight method of storage and it is found that some of the traditional methods, like storage in earthen pots, satisfy these conditions. Similar conditions are obtained in modern methods by employing mechanical means. It is not possible, however, to use mechanical devices in all places as it enhances the cost of storage considerably. Work is therefore, necessary to simulate and reproduce some of the characteristics of the traditional methods of storage in modern structures thus bringing within the reach of all, cheap, simple and safe methods of storage.

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Progress in the Mechanization of Farming in the Colonial Territories—II

A Visit to the British Territories in West Africa

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Attention has been drawn[1] to the suggestion that ' economic ' mechanization must depend upon the use of standard, or near-standard, quantity-produced equipment. Cheapness and versatility are also important. Specialized local requirements can rarely be met with machinery which is sufficiently cheap, versatile and supported by spare parts and service facilities.

Progress in introducing modern quantity-produced equipment into tropical agriculture has been reviewed with particular reference to Central Africa, East Africa and the High Commission Territories following a fact-finding tour in 1953. The present paper is based on a similar tour in West Africa.

THE TOUR

During April–July 1954, the writer visited the Gambia, Sierra Leone, the Gold Coast, and the three Regions of Nigeria under the auspices of the Colonial Agricultural Machinery Advisory Committee, and with the very helpful co-operation of the territorial governments. A mass of information was collected (much of the detail concerning the mechanical performances of machines) from which the following general conclusions were drawn:

(*a*) There will be little expansion of agricultural mechanization in the *Gambia* for several years. *Sierra Leone* may develop very big plans for rice production on inland swamps and riverain grasslands. In the *Gold Coast* there is great popular interest in mechanization and the whole subject is being investigated very thoroughly by the Government and the University College; but the difficulties are considerable. In *Nigeria* interest is concentrated on rice production and general tractor ploughing; and noteworthy progress is being made at the agricultural engineering headquarters in the Northern Region. Disappointments have been experienced in several commercial mechanized agricultural production schemes.

(*b*) There would be considerable interest in bulletins on tropical agricultural engineering. Such work should not be limited to matters of strictly British territorial interest, and should be in an authoritative permanent form to facilitate cataloguing and storage.

(*c*) Considering the difficulties of local conditions, the territorial departments of agriculture are to be congratulated on the extent of the experience of mechanization which they have gained in a comparatively short time.

(*d*) Skill and experience in management can be much more important than technical skill—especially in colonial conditions.

In addition, the general conclusions drawn[1] after the visit in 1953 to eastern and southern Africa were endorsed in relation to West Africa; although the immediate requirements of the African farmers for agricultural machinery were found to be much less than in eastern and southern Africa. This is due, presumably, to the absence from British West Africa of a community of settler farmers or plantation companies from whom the indigenous population might have gained much technical knowledge by observation and example.

COST OF MACHINERY OPERATIONS

The high cost of machinery operations, described in some detail in the previous paper, appeared to be even more significant in West Africa, mainly because the farming is less developed commercially than in eastern and southern Africa, skilled mechanics are not so readily available, and spare parts are not so easily distributed.

Tractor Running Costs—It was difficult to reconcile various estimates of running costs made by different authorities. The basis and significance of cost accounting was not understood on several stations or projects. Cost accounts were often based upon a log-book record only. The use of tractor-hour counters, or rotating chart recorders was not widespread. In some costings no allowance was made for overhead expenses; in others, no provision was made for replacement; and in yet others the full costs of repairs, buildings and supervision were being charged as they arose. Some misleading figures had been publicized by commercial interests in the Gold Coast in which no mention had been made of repairs, parts, and capital costs. It was also not fully appreciated that a charge for ' depreciation ' can only cover *either* the repayment of capital, *or* the replacement of the machine, but not both.

Figures intended to indicate the cheapness of mechanical operations are likely to be misguided. Better ends would be served by emphasizing the possibilities of increasing production, and thus profit.

LOW CROP YIELDS

Extremely low crop yields were being experienced on many projects. On some, the records indicated that mechanical operations would become economic if yields were increased threefold. Such increases would not be inconceivable, but exhaustive agronomic investigations would be necessary. More might be discovered about the effects of crop residues and green manures on the nutrient state and mechanical condition of the soil, as compared with chemical fertilizers and mechanical treatments such as subsoiling. The whole field of trash farming would be worth investigating in the savannah areas. Fertilizer treatments are already being investigated widely, and problems of mechanical placement are receiving some attention. In some areas it may be necessary to investigate the difficulties of transporting, storing and marketing increased quantities of produce.

MANUFACTURERS' AGENTS

The remarks under this heading in the previous paper[1] apply equally in principle to West Africa, although the whole trade in agricultural machinery

is much less than in East Africa, and the problems associated with dollar-area goods are less acute. In the Gambia and Sierra Leone there is no really effective agricultural machinery agent, because the trade is negligible at present.

TECHNICAL PROGRESS

Paddy Cultivation—Most of the development of paddy growing in West Africa has taken place on inland swamps and natural flood plains without means of water control. Tractor adhesion problems are associated with extremely dry soil as well as wet. Mechanical operations are directed towards *either* small-scale ploughing for peasant producers, *or* large-scale ploughing and, possibly, drilling of seed for peasants. Particular mention should be made of the Gambia Rice Farm where paddy-growing techniques are being thoroughly investigated with an extensive irrigation system, the dry-season cultivation of inland swamps and riverain grasslands in Sierra Leone where the Department of Agriculture ploughed about 8,000 acres in 1954, and the Sokoto fadama-ploughing project, at present under administrative reorientation, which achieved no less than 37,000 acres in its peak year.

A recent survey[2] of rice soils in the British colonial territories showed that there were two main types in use:

(*a*) *Clays*, in which a relatively firm ' bottom ' can be found at a depth of 6 to 12 in.—at least at the beginning of the season;

(*b*) *Silts and silty sands*, in which no firm ' bottom ' can be found near the surface once the land is flooded.

The *Peats* vary greatly in their characteristics, but usually have a surface mat of organic matter which, if unbroken, can bear a considerable distributed weight. Very little use is made of them for rice production. It is possible that they will become more important as populations increase.

Many of the rice soils in West Africa appear to be of type (*b*) and if the water rises early in the season all mechanical work may be halted long before the normal planting date. If mechanization is desired it will be necessary either to increase the number of controlled irrigation schemes or to investigate the possibility of using long-standing varieties.

Current thought on methods of obtaining adhesion and traction on paddy land have been reviewed elsewhere[2] and a new commercial development has been described which gives the tractor stability and flotation by cage type extensions to the standard pneumatic tyre equipment. The extensions, about 12 in. wide, are slightly less in diameter than the tyres so that road travelling is not affected. The tractor can be fitted with a hydraulic depth-controlled mounted disc harrow and levelling board combination. Reports received from India have justified the production of a large consignment of this equipment.

It is possible that cable-haulage tackle could be developed for use in some very flat areas (such as delta soils or mangrove swamps) where large paddy fields could be laid out on the square and the intervening bunds could be made wide enough to accommodate compact power units. At least one machinery manufacturer is prepared to co-operate in any such project.

Paddy harvesting—Self-propelled combine harvesters are working successfully in one or two places in West Africa, but they are rare because they are

expensive and can only be economical when a considerable acreage is harvested each year. For a 10 ft. combine harvester 150 acres or more might be economical, depending on the length of harvesting season. Potential customers are reluctant to buy a machine requiring considerable experience in handling and maintenance.

A new trailed combine harvester of 4 ft. cut, power take-off driven, is being adapted for use in paddy. Trials were to be held in France in October 1954. The combine will be fitted with a peg drum, peg concave, and balloon tyres. Harvesting equipment which has recently been used elsewhere includes a tractor-mounted head harvester (Malaya), a tractor-mounted power-driven binder (Italy) and a reaper-type mower with a manually operated sheaf board which leaves the loose sheaves on the ground to be tied by hand. While the latter is not considered to be a final answer to the rice harvesting problem, it might possibly meet a current requirement in parts of West Africa.

Brush and Weed Control in Perennial Crops—The use of machinery in the production of established export crops appears to be the most logical starting point for mechanization in the agriculture of any territory, but oil palms and cocoa are seldom planted or tended in such a way that mechanization of field operations would be possible. It is, nevertheless, interesting that trials of bush-cutting machines are starting at the West African Institute for Oil Palm Research, Benin City. The problem is to control underbush in plantations without disturbing the soil. In the early stages stumps and logs remain on the land, but in later years the bush consists largely of grass, vines and some small shrubs. A rotary cutter and a duplex roller cutter are now in use. No British machine is available at present, although one is said to be in development. Similar work has been done in the Belgian Congo[3].

Palm Nut Cracking—Excellent results are reported to have been obtained in Sierra Leone following the development of a small engine-driven palm nut cracker which has now been put into commercial production in the United Kingdom. Trial units have been sent to the Gold Coast.

Land Clearing—There is considerable difference of opinion about bush-clearing methods. The tendency at present is to do the job by hand, or with small mechanical aids, and to develop the land slowly, possibly even planting and cultivating by hand during the first year or two. Complete clearing and logging of wide areas by tractor is likely to be expensive and dangerous from the point of view of soil conservation, and yet it is possible that undue emphasis is put upon the dangers of disposing of bush by burning. Reports from the Belgian Congo indicate that a small degree of mechanization in clearing forest may lead to the saving of labour, but no immediate economic advantage has been demonstrated.

It appears that special mechanical arrangements for clearing mangrove swamps may not be necessary in West Africa. Even where the demand for mangrove land is considerable, hand clearing methods appear to be quite adequate for agricultural purposes. In some areas individual farmers preferred to clear new land by hand rather than compete with sedges and grasses on the old land.

SUMMARY

This paper enlarges upon some of the conclusions drawn after visiting West Africa to see progress in the mechanization of agriculture. Several general conclusions drawn following a visit to East Africa during the previous year were endorsed in relation to West Africa. The cost of mechanization is emphasized, particular mention being made of the importance of record keeping. Some technical developments are reviewed briefly.

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Copper : Its Occurrence and Role in Tea Leaf

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' From supposed poison to nutrient in twenty-five years ', that is the story of copper, as F. A. Gilbert points out in his review ' Copper in Nutrition '[1]. Tea affords a good illustration of his epigram.

In 1910, as a result of a scare in America over the sale of grapes sprayed with Bordeaux mixture, Annett and Kar[2] in India studied the amount of copper taken up by tea sprayed with this fungicide as a protection against ' Blister Blight '. They found 71 p.p.m. of copper in sprayed tea as against 12 p.p.m. in unsprayed tea; they demonstrated that little of this copper went into the cup and concluded that there was no hazard involved in copper spraying of tea.

The spread of Blister Blight (*Exobasidium vexans* Massee) to Southern India and Ceylon in 1946, to Sumatra in 1949, Malaya in 1950 and Java in 1951, led to intensive study of protective measures in these countries. The use of copper fungicides has been found highly effective and is now routine practice. The possibility of undue contamination with copper of the made tea received due consideration, and in 1951 the Ministry of Food approved for publication a report of its Food Standards Committee[3]; this allowed a provisional limit of 150 p.p.m. of copper in tea. Only a fraction of this copper is soluble, and the content of copper in the liquor would not normally exceed the 2 p.p.m. allowed for other beverages.

Incidental to this work, information became available on the normal natural content of copper in Southern India and Ceylon tea leaf. For the former, figures ranging from 18·2 to 38·7 p.p.m. have been recorded; the indications were that the natural copper content of China and hybrid teas is normally greater than that of the Assam varieties[4]. The range of values reported from Ceylon is similar, and clonal differences are apparent. In the Annual Report of the Tea Research Institute of Ceylon for 1947[5] figures are given for the copper content of leaf from seven clones:

Bush number	*Cu content of flush (mg/kg)**
R4P7	20·6
R2P7	16·2
R3P3	30·5
R2P3	19·4
R1P3	24·0
R5P3	29·2
R6P3	22·8

* Erroneously given in the original as mg/gm.

Only in 1931 was it first clearly recognized that copper is an essential micronutrient for the growth of higher plants, and although the occurrence of copper deficiency symptoms in tea affecting growth has not been formally demonstrated, it is difficult to resist the conclusion that copper spraying frequently has a tonic effect apart from the control of disease.

TEA FERMENTATION

The first hints that copper plays a role in the fermentation of tea leaf came in 1937 from laboratory work in Ceylon and field studies in Nyasaland. HORNBY[6] reported that the poor fermentation of leaf grown in certain areas in the high-rainfall belt of Mlanje, Nyasaland, was improved by spraying the bushes with copper solutions and suspensions.

At the same time investigations on the enzymes involved in the tea fermentation process were in progress at the Research Institutes in India and Ceylon. The Ceylon workers followed up the hint provided by the Nyasaland field observations in conjunction with the recognition by KEILIN and MANN[7] that the polyphenol oxidase from mushrooms was a copper protein complex; and in 1943[8,9a] presented evidence that the oxidase was a metallic protein with copper as its prosthetic group. Enzyme preparations were concentrated to a degree of activity at least 800 times that of the original leaf; in the more active preparations the polyphenol oxidase activity (measured by Sreerangachar's ascorbic acid method)[9b] was proportional to the amount of copper present.

The purest preparation obtained had an activity of 10,100 units/hr/gm, *i.e.* under specified conditions 1 gm catalysed the oxidation of 10,100 mg of ascorbic acid; it contained 0·08 per cent of copper and 6·60 per cent of nitrogen. Complete removal of copper, *e.g.* by means of potassium cyanide, inactivated the enzyme; re-synthesis by adding copper sulphate was not found possible, in contradistinction to the experience of KUBOWITZ[10] with oxidase from potatoes.

SREERANGACHAR's[9a] regression between copper content and oxidase activity indicates a ratio of 8 μg copper per 100 units of activity. He claimed that this was reflected in crude preparations obtained from bushes whose leaf showed a wide range of activity:

Activity of acetone-extracted leaf powder	*Cu. p.p.m.*
224 mg/gm	20
193	16
185	16
80	4

As a result of this work, it clearly became of importance to see whether the fermenting quality of leaf in the factory was related to its copper content. Reference has already been made to a suggested copper deficiency of Nyasaland tea leaf and its connection with poor fermentation. According to HARLER[11] analysis of leaf from the Mlanje areas ranged from 7 to 15 p.p.m.; when poorly fermenting tea was sprayed with Bordeaux mixture fermentation became normal in a day or so, and the effect from one spraying lasted about two years. Later recorded analyses from Nyasaland have been of the same order[12], 12 to 16·5 p.p.m. for normal tea, with some

figures down to 8·5 p.p.m. Applications of copper to the soil were stated by Harler to be valueless, owing to fixation, particularly in soils of high organic matter content.

In Malaya[13], inconclusive results were obtained by spraying the soil with copper sulphate solution, though there was some evidence of improved fermentation and quality by this means. The natural copper content of tea leaf from the Cameron Highlands was reported as 18 to 20 p.p.m., at Serdang Experimental Station the copper content of tea leaf ranged from 12·8 to 16·2 p.p.m. (average 14·7)[14].

In the Annual Report of the Tea Research Institute (Ceylon) for 1943[15], reference is made to ' a non-fermenting bush, the enzyme copper content of which was only about a fourth or a fifth of that of a normal bush '. Increasing the copper status of leaf, *e.g.* by Roach's injection technique, or by keeping over night flush with stalks immersed in dilute copper sulphate solution, was stated to increase enzyme activity; by the second method ' in some cases a five to sixfold increase in enzyme activity was observed, the latter being estimated by the ascorbic acid method '.

In 1944[16], it was stated that mere addition of copper sulphate to the crushed leaf did not cause any increase in the rate of fermentation as observed by factory criteria. In the field, a row of clonal bushes was divided into two halves, and one half sprayed with Bordeaux mixture. Sixteen successive manufactures were carried out at 9 to 10 day intervals. There was a significant increase in the copper content of flush from treated bushes and a marked increase in colour in the treated leaf when fermented, though little difference in quality.

Both in field and laboratory, a general connection between copper status and fermentability of tea leaf may be said to have been demonstrated. The relationship is not altogether a simple one, however.

The writer[17] determined the copper content and the oxidase activity on 58 consecutive samples of selected (' two and a bud ') flush plucked at 10 day intervals between 2 April 1952 and 24 October 1953, from an experimental plot at Kericho, Kenya Colony. The average copper content was 14·94 p.p.m. with a range of 12·0 to 18·7 p.p.m. and a standard deviation of 1·93. There was no relation between the enzyme activity figures which showed a much wider range, 128 to 276 mg ascorbic acid/gm leaf.

The copper figures for normally fermenting leaf reported from East Africa, Nyasaland and Malaya are considerably lower than those from Ceylon and Southern India. Moreover, the Ceylon bush No. R2P7 with a copper content in its leaf of 16·2 p.p.m. is described as a ' non-fermenter '[4].

A more serious divergence is presented by the lack of relationship between the copper content and enzyme activity of different parts of the flush. Over 50 years ago H. H. Mann noticed the high activity of the stalk[18], and similar results, using the Sreerangachar method, have been more recently reported from Ceylon[19]. No copper figures were, however, recorded.

The author has reported[17] results for copper and enzyme activity by the ascorbic acid method on acetone-extracted powders from flush dissected into six portions. *Table 1* summarizes the results of one set of experiments.

Table 1. Copper and Enzyme Contents of Flush

	Copper p.p.m. *of dry leaf*	Cu. p.p.m. *(of leaf) extracted by acetone*	Cu. in *enzyme prep. by difference*		*Enzyme activity* mg. *ascorbic acid*/gm *dry powder*
			as p.p.m. *of leaf*	*as* p.p.m. *of enzyme powder*	
Expt. 6					
Bud	17·2	2·5	14·7	27·7	512
1st leaf	14·2	1·6	12·6	23·5	258
1st stalk	11·6	—	—	—	628
2nd leaf	13·2	1·1	12·1	21·1	224
2nd stalk	13·4	3·0	10·4	16·0	428
3rd leaf	12·7	1·5	11·2	18·7	170
Expt. 8					
Bud	25·0	9·0	16·0	31·5	479
1st leaf	14·3	1·4	12·9	24·0	328
1st stalk	12·3	1·4	10·9	20·6	665
2nd leaf	11·2	—	—	—	225
2nd stalk	11·6	1·3	10·3	17·0	462
3rd leaf	11·3	0·7	10·6	17·6	170

There is nothing in the copper content of the stalks to account for their higher enzyme activity.

It is clear that other factors are involved. A partial explanation will probably be that the ratio of enzyme to non-enzyme copper in the plant may be very variable; oxidase activity need not necessarily be proportional to *total* copper. Secondly, it is probable that in fermentation the enzyme system is not simple; other enzymes than polyphenol oxidase are undoubtedly involved. Thirdly, there is the possibility that inorganic inhibitors may be involved, such being more abundant in the leaf than in the stalk.

Soil Considerations

Nevertheless, there is evidence enough that copper deficiencies leading to poor fermentations do occur. The writer[20] has recently examined samples of leaf from eight estates in the Tukuyu district of Southern Tanganyika, from which complaints of poorly fermenting leaf had come. The samples ranged from 7·9 to 13·1, with an average of 11·0 p.p.m.; the lowest figure was for a sample from an area of black volcanic soil near Mount Rungwe.

It is perhaps significant that the lowest copper contents of tea leaf have been recorded from Southern Tanganyika and Nyasaland, countries in which occurs sulphur deficiency leading to ' tea yellows '. Geologically copper and sulphur are closely associated; the formation of sulphides dominates the geochemistry of copper[21].

Clonal Differences

The Ceylon and Southern India investigations referred to give indication that clones differ notably in their ability to take up copper, and possibly also in their ability to synthesize copper-protein complexes. Through the courtesy of the Tanganyika Tea Coy., Ltd., the writer[20] was able to examine

leaf samples from six clones, and also from five of the corresponding mother bushes grown at Mufindi, Tanganyika:

No.	*Cu. content (p.p.m.) clonal samples*	*Cu content (p.p.m.) mother bushes*
20	10·7	—
28	15·8	15·8
31	13·4	13·2
33	15·0	16·4
35	13·3	13·3
50	14·7	13·6

More research on this aspect of copper is clearly desirable.

Copper in Made Tea

During rolling, tea leaf picks up small amounts of copper from brass rollers. In Ceylon this was clearly demonstrated by a series of analyses at various stages of manufacture using wooden and brass rollers respectively[22] :

Table 2. Increase of Copper Content During Manufacture in Wooden and Brass Lined Rollers*

Material	*Copper content*	
	Wooden roller	*Brass lined roller*
	p.p.m.	p.p.m.
Withered leaf	25·5	25·5
1st dhool	24·0	32·5
2nd dhool	25·5	34·0
3rd dhool	28·3	36·5
4th dhool	25·0	33·5
Made tea	27·0	34·0

* From : *Ann. Rep. Tea Research Institute, Ceylon*, 1950, *Bull. No. 32*, p. 27.

Gunn Lay Teik[14] in Malaya obtained similar figures using brass roller tables:

	Sample No.	*Cu fresh leaf p.p.m.*	*Cu made tea p.p.m.*
14.1.54 from sprayed plot	A	19·4	23·7
,, ,, control	B	14·6	23·7
26.1.54 ,, sprayed plot	C	18·4	24·1
,, ,, control	D	12·8	24·1

The writer[20] obtained the following figures for the various grades from a Kericho, Kenya, factory, the original unselected leaf having Cu 14·6 p.p.m.:

	p.p.m.		*p.p.m.*
Dust I	19·2	B.O.P. I	19·0
Dust II	29·4	B.O.P. II	25·8
P.F.	25·6	Grade 3	19·0
Pekoe	22·2		

This is in agreement with the Ceylon findings[22] that fannings have a higher content than B.O.P.

A sample of made tea from a Tukuyu factory—a B.O.P.—had Cu 28·4 p.p.m. against 10·8 p.p.m. in the original leaf.

It appears that the leaf in the course of manufacture may pick up between 4 and 20 p.p.m. of adventitious copper. Curiously, McCance and Widdowson[23] found a mean content of 15·9 p.p.m. in five samples of Indian Tea, as purchased retail and analysed by them—a surprisingly low figure. They state that only a trace of the copper goes into the liquor.

Cobalt

Harler (*loc. cit.*)[11] stated that copper sprays using pure copper sulphate were ineffective in comparison with those made from the commercial salt; this was said to be due to the presence of cobalt in the latter.

This claim repeats an earlier one implicit in a report from Nyasaland in 1940[24]. It has not received confirmation and seems improbable in view of the minute amount of cobalt (less than 1 p.p.m.) since recorded in tea leaf from Nyasaland[12].

SUMMARY

No disease resembling ' exanthema ' of citrus or ' reclamation disease ' of small grain crops, due to copper deficiency has been established for tea, though there is little doubt that the element is essential for growth. There are indications that copper sprays have a ' tonic ' effect apart from their function in combating disease.

Copper is an essential element in the fermentation of tea leaf; the polyphenol oxidase involved in fermentation being a copper protein. Unsatisfactory fermentations seem to be associated with copper contents of tea leaf below 12 p.p.m.; the quantitative evidence is, however, conflicting —the Ceylon workers would put the deficiency limit higher than 12 p.p.m. The difference may be partly due to variation in the ratio of enzymic to non-enzymic copper in the plant; to the presence or otherwise of inhibiting substances; or to the complexity of the multi-enzyme system involved in fermentation. Future laboratory research must be aimed at clarifying these questions. In districts where unsatisfactory fermentations are met with, field research seeks practical methods of increasing the copper status of the tea bushes.

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The Effect of Plot Shape in Reducing the Errors of Tea Experiments

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INTRODUCTION

A volume of work has been published on the reduction of positional variation in field experiments with annual crops by the use of suitably shaped plots and blocks and, in general, narrow plots within broad compact blocks are found to be best. References illustrating this conclusion are many and the work of Christidis[1,2], and MacDonald, Fielding and Ruston[3] may be quoted as examples. No such volume of work has been published for perennial crops, and Pearce[4] whilst reviewing and considering previous work on perennials states, ' In general, plots should be long and narrow—a conclusion that has been demonstrated empirically for certain annual species and doubtless applies to perennial also. Indeed it is the counterpart of the rule that blocks should be compact; because whereas blocks should be associated with positional differences, the plots of a block should resemble one another as much as may be '.

Eden[5] analysed data from a uniformity trial with tea in Ceylon and recommended a plot size of about 1/18 acre, or some 100 to 150 bushes with tea planted at four feet square. No account was taken of the effects of plot shape and the uniformity plots were built up into square ' treatment ' plots arranged in latin squares. Eden also states, ' that elimination of positional variance is shown to be inferior to that generally obtained on annual crops in temperate climates, but this inferiority corresponds with similar experience on other tropical crops '.

No specifically designed uniformity trial with tea has been or is being done in Nyasaland and a plot size of 100 to 150 bushes has been used wherever possible. A re-examination of yield data from two uniformity trials recorded in preparation for subsequent experimental treatments, indicates that narrow plots, suitably orientated, are superior to square or broad ones and a re-examination of Eden's data from Ceylon appears to confirm this.

Although the Nyasaland data is obtained from plots not specifically designed in size or in number, according to the usual methods of this type of investigation, the effects of plot shape are sufficiently consistent as to leave little doubt as to their general validity though in practice field treatment plots will be about one-quarter of the area of the composite plots used in the analyses described below. The Ceylon data allow uniformity units to be built up into treatment plots of a size which would be about adequate for experimental purposes. The results are presented with these reservations in mind and no originality of concept is claimed for the methods used.

METHOD

In order to avoid confusion, uniformity plots will be called ' units ' and the combined groups of these used in the analyses called ' plots '. Units were grouped together to give variations in plot and block shape whilst keeping the areas of both constant for each set of calculations. Randomized block layouts were used and the efficiency of sampling assessed by expressing the standard error of the design as a percentage of the mean plot yield (percentage coefficient of variation, or C.V. per cent). A remainder sum of squares was preferred to a true error line in order to avoid bias in the error caused by variation associated with re-randomizing hypothetical treatments for each new arrangement. This can be high, especially so when the plots are sampling badly and spurious treatment differences are high enough to give a large treatment sum of squares which unfairly reduces the error. By using a remainder the efficiency of any arrangement is therefore assessed purely from the effects of plot and block shape.

The top of the page will be to the north and length to breadth of plots and blocks indicated by a ratio; length always being measured north–south and shown first in the ratio. In the figures blocks are indicated by broken lines.

TEA RESEARCH STATION, NYASALAND

A uniformity trial over 23 plucking rounds was completed in 1942 in preparation for a fertilizer trial. Thirty-two units were recorded each being 10 by 15 bushes (0·67:1). *Figure 1 (a)* shows the unit layout, their yields in pounds of made tea, and superimposed are physical contours spaced at 2 ft. vertical intervals. Four units make one plot and four plots, contained in each of two blocks, are variously arranged as in *Figure 1 (b)* to *1 (f)*. Analyses of variance of these arrangements are given in *Table 1*.

Table 1. Tea Research Station, Nyasaland

	Plots	0·67:1	2·63:1	0·67:1	2·63:1	0·17:1
	Blocks	0·67:1	0·67:1	2·63:1	2·63:1	0·67:1
	Figure	*1 (b)*	*1 (c)*	*1 (d)*	*1 (e)*	*1 (f)*
Sums of squares	*Total*	1738	1513	1738	1513	1693
	Blocks	1250	1250	27	27	1250
	Remainder	488	263	1711	1486	443
	C.V. *per cent*	6·80	5·00	12·73	11·87	6·48

Between the four arrangements *1 (b)* to *1 (c)* the lowest C.V. per cent, and hence the best sampling, has resulted from narrow plots within broad blocks, arrangement *1 (c)*. Of the total sums of squares which reflects the effect of plot shape, a reduction of 225 has resulted from good plot shape. A proportionately bigger reduction of 1,223 has resulted by the use of broad blocks. The row totals *Figure 1 (a)* indicate that the more pronounced fertility trend is with the slope of the land and it might be expected that sampling errors would be increased by using very broad plots lying with their longer axis across the slope, *Figure 1 (f)*. The expectation has been achieved and this arrangement increases the C.V. per cent to 6·48 per

cent against 5·00 per cent for arrangement *1* (*c*) which has nearly the same block and plot shape, but with the longer axis of the plot running down the slope.

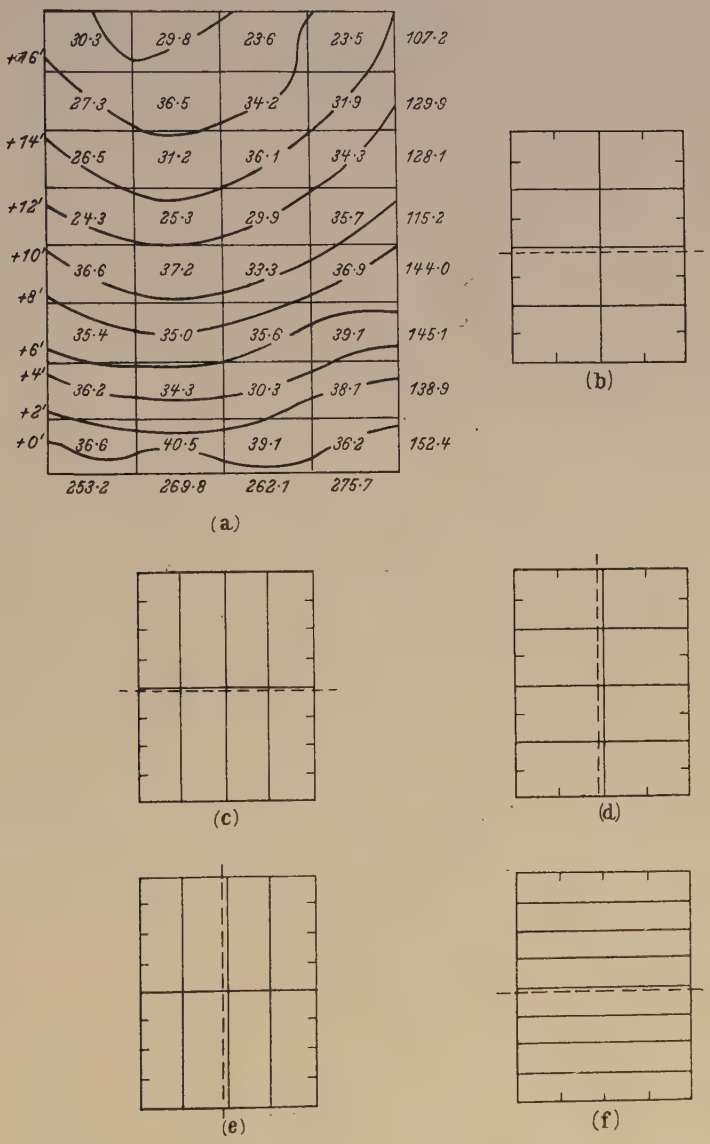

Figure 1. Tea Research Station, Nyasaland

MIANGA ESTATE, NYASALAND

In preparation for two complete replications of a three cubed factorial design, 54 units were recorded for yield over 18 plucking rounds during the

tea season 1951/52. Mianga Estate lies in a district of broken ground where level or gently sloping fields are rare and the garden was the most suitable that could be found for experimental purposes, although it was appreciated at the outset that it was not ideal.

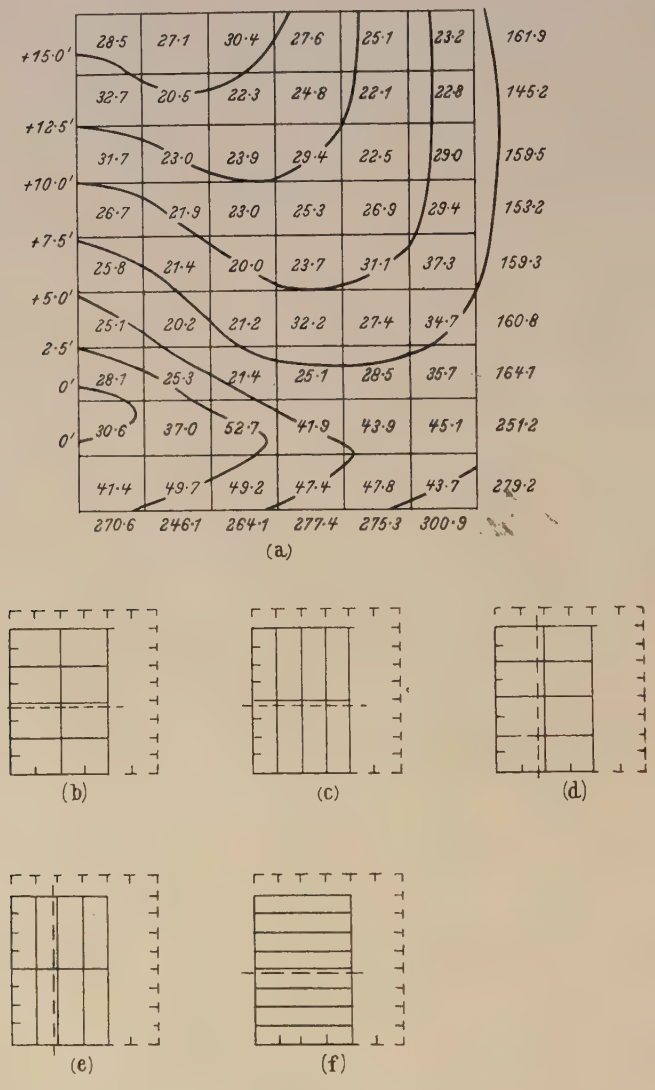

Figure 2. Mianga Estate, Nyasaland

Figure 2 (*a*) shows the layout of units each nine by eleven bushes (0·82:1), their yields in pounds of made tea, and physical contours at two-and-a-half feet vertical intervals. Thirty-two of the fifty-four units were used in this series of calculations and were built up into plots of four units each, there

being four plots in each of two blocks. Each plot is thereby about four times the usually accepted experimental area. Plots and blocks were arranged as in *Figure 2* (*b*) to *2* (*f*) and analyses of variance of these arrangements are given in *Table 2*.

Table 2. Mianga Estate, Nyasaland

	Plots	0·82:1	3·33:1	0·82:1	3·33:1	0·20:1
	Blocks	0·82:1	0·82:1	3·33:1	3·33:1	0·82:1
	Figure	*2* (*b*)	*2* (*c*)	*2* (*d*)	*2* (*e*)	*2* (*f*)
Sums of squares	*Total*	9295	3797	9295	3797	9105
	Blocks	2903	2903	63	63	2903
	Remainder	6392	894	9232	3734	6202
	C.V. *per cent*	27·64	10·34	33·22	21·13	27·22

As with the Tea Station data, the best result has been obtained by using narrow plots running down hill and enclosing these in broad blocks, arrangement *2* (*c*). A reduction of 5,498 has been obtained in the total sums of squares by the use of narrow plots and reduction of 2,840 by the use of broad blocks. Very broad plots lying across the slope, *Figure 2* (*f*), increase the C.V. per cent to 27·22 against the 10·34 per cent of the best arrangement, *Figure 2* (*c*).

CEYLON DATA

In 1928, EDEN[5] divided an area of tea into 12 rows and 12 columns of approximately square uniformity units, each six by seven bushes, and recorded yields from these over 44 plucking rounds. Unit arrangement with row and column totals in pounds of made tea are shown in *Figure 3* (*a*) and detailed unit yields are recorded in the original paper. No physical contours are marked on his basic plan although the north–south and east–west slopes are shown by scale sections which indicate that the major slope is north–south.

Six units are included in each plot and there are six plots in each of four blocks. The plot size is slightly larger than that usually preferred.

Plot and block arrangements are shown in *Figure 3* (*b*) to *3* (*f*) and analyses of variance in *Table 3*.

Table 3. Ceylon Data

	Plots	0·67:1	5·88:1	0·67:1	5·88:1	0·17:1
	Blocks	1:1	1:1	4:1	4:1	1:1
	Figure	*3* (*b*)	*3* (*c*)	*3* (*d*)	*3* (*e*)	*3* (*f*)
Sums of squares	*Total*	9,091,154	3,034,522	9,091,154	3,034,522	11,040,764
	Blocks	222,502	222,502	670,544	670,544	222,502
	Remainder	8,868,652	2,812,020	8,420,610	2,363,918	11,018,362
	C.V. *per cent*	11·41	6·43	11·11	5·89	12·82

The lowest C.V. per cent has been obtained by using narrow plots running down the slope and enclosing these in narrow blocks also running down the slope. A reduction of 6,056,632 has resulted in the total sums

of squares by the use of narrow plots running up and down the slope. Very broad plots running across the slope *Figure 3* (*f*), result in an increase in the total sums of squares which increases the C.V. per cent to the highest value of all five arrangements.

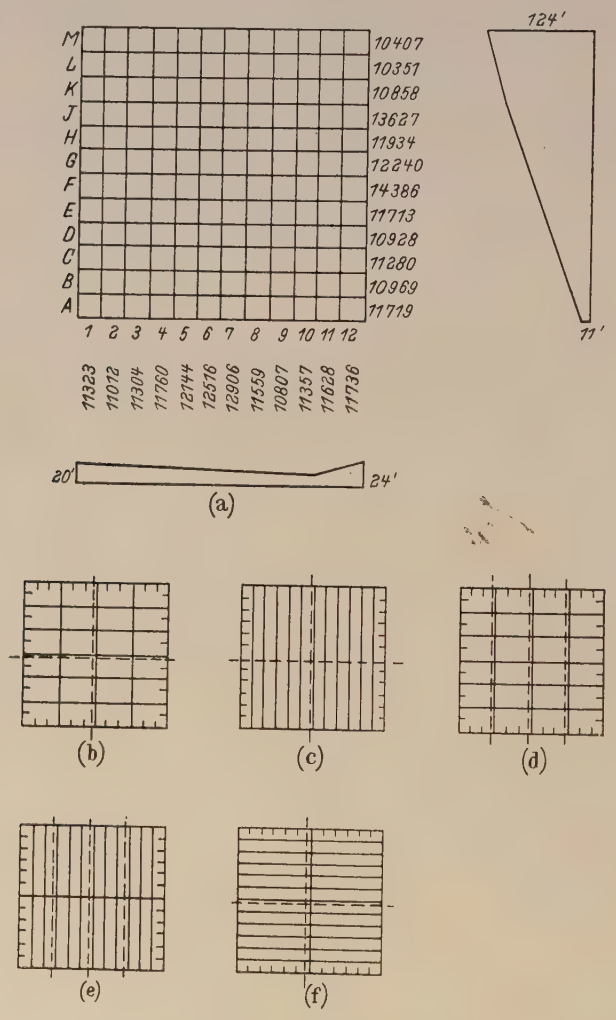

Figure 3. Ceylon data

The effects of block shape are in contrast to those obtained with the Nyasaland data, although the reduction in error is proportionately more by good plot shape than by good block shape.

SLOPE AND ORIENTATION OF PLOTS

In all three sets of calculations above, the consistent result has been obtained that narrow plots running up and down the physical slope reduce

error. All the 54 Mianga units were used to examine this conclusion in a more detailed manner.

From *Figure 2* (*a*) it will be seen that there are two major directions of slope in this garden. In the western side and the south-eastern corner of the field the slope is south down to a valley and then a rise again further south. A shoulder occurs in the north-eastern part and throws the slope in this section downwards to the east.

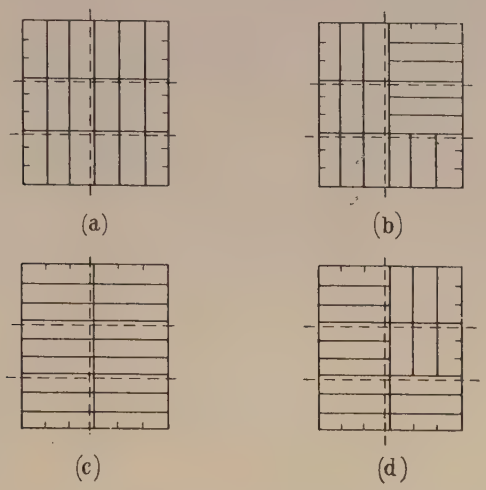

Figure 4. Mianga, plot alignment according to slopes

Three units compose one plot and three plots are variously arranged in each of six blocks as in *Figure 4* (*a*) to *4* (*d*). Analyses of variance are recorded in *Table 4*.

Table 4. Mianga, Orientation of Plots According to Slope of the Land

	Plots	*All* N.S.	N.S. *and* E.W.	*All* E.W.	E.W. *and* N.S.
	Figure	*4* (*a*)	*4* (*b*)	*4* (*c*)	*4* (*d*)
Sums of squares	*Total*	7400	7254	10286	10432
	Blocks	6386	6386	6386	6386
	Remainder	1014	868	3900	4046
	C.V. *per cent*	10·12	9·37	19·86	20·23

The lowest error is obtained when the plots within the blocks are arranged as nearly as possible to run with the slopes, *Figure 4* (*b*), and it will be noted that within the two north-eastern blocks the plots run east–west. The remaining arrangements become progressively worse as the plot orientation brings them nearer to lying across the two main slopes.

FIELD PRACTICE

The method of arranging plots in *Figure 4* (*b*) illustrates a feasible but perhaps unusual field arrangement. A rather similar method has been used at the Tea Research Station in laying out a ' three to the fourth ' design

in nine square sub-blocks, each of nine plots. In eight blocks it was possible to arrange the plots on the same slope, but owing to physical obstructions, the ninth block occupied a different slope and plots were accordingly turned to run downhill being, in fact, at right angles to the remainder. The ratio of length to breadth in these plots is 9:1.

Orientation of plots usually presents no difficulties as the standard field practice is to contour-drain Nyasaland tea areas before planting.

In the above calculations the effects of block shape in reducing error have not been so consistent as the effects of good plot shape, but in two of the three examples broad blocks were more effective than narrow ones. In lieu of more definite information, broad compact blocks are used based upon the following argument. As little positional variation as possible is required in treatment plots and this condition is best obtained by using suitably orientated narrow plots. As much positional variation as possible is required to be accounted for by blocks and this should best be obtained by using blocks opposite in shape to good plots *i.e.* broad blocks.

Confounded or partially confounded designs besides offering a reduction in error by the use of sub-blocks *per se* are also of distinct practical benefit with Nyasaland tea experiments. Physical obstacles, primarily large ant hills, are a particular nuisance and very rarely is it possible to obtain for an experiment a sufficiently large area of land without these obstructions. (The Nyasaland data used in the above calculations were chosen because these two experiments occupy compact areas of land.) Under these conditions the use of relatively small sub-blocks offers a most useful method of land utilization because they can be arranged clear of obstructions and thereafter positional differences between widely spaced sub-blocks can be accounted for in the analysis of variance. Further benefits of blocks are obtained by arranging work programmes in such a way that differences of skill or time are equalized over blocks and thereby do not enter into the assessment of treatment differences.

SUMMARY

(1) Three areas of tea, two in Nyasaland and one in Ceylon, provide uniformity units which were arranged to give variation of plot and block shapes.

(2) At each site, plot and block areas were kept constant and an assessment of the efficiency of each arrangement was made by calculating the standard error of the experiment expressed as a percentage of the mean plot yield (C.V. per cent).

(3) Narrow plots running with the slope were always superior to broad plots or to very broad plots across the slope.

(4) The effects of block shape were not as consistent, but in two out of three cases broad blocks were more effective than narrow ones.

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Weeds in Rice and their Control in Suriname

J. G. P. Dirven and H. Jonge Poerink*

Of the agricultural crops cultivated in Suriname, rice is without a doubt the most important. More than 19,000 hectares are planted with this crop, the average yield being about 3,000 kg of unshelled rice per hectare.

Over 90 per cent of the rice produced comes from small family-sized farms, and most of these farms have an area of between 0·5 and 3 ha. Rice is grown on these small farms by the transplanting method, in which the young rice plants grown in the seed beds are transplanted by hand in the wet rice fields. Since the canopy is closed rather early by the use of this method, the weeds have little chance of developing.

Before transplanting, the rice fields are tilled. Part of the fields are only weeded, but the majority are ploughed and harrowed, either by draught animals (plough-oxen) or by tractors. Increasing mechanization may be observed, especially in recent years. In connection with this the government is allocating to the farmers larger areas of land (4, 8, 16 ha) in newly made polders.

The variety of rice most used by the indigenous population is Skrivimankoti which, however, is not very suitable for mechanized agriculture owing to its pronounced tendency to lodging. Therefore up to now the mechanized farms have mostly planted varieties from the United States (Rexoro, Bluebonnet) which are non-lodging but which have a much lower yield. However, considerable advances have already been made with the selection of new varieties with strong straw, high yield and good quality.

The Wageningen scheme is also of great importance to the mechanization of rice cultivation in Suriname. This scheme envisages the reclamation and empoldering of 50,000 ha of swamp in the Young Coastal Plain for the establishment of highly mechanized farms. A start has been made with the laying-out of a 5,000 ha polder, which will be divided into 64 farms of 72 ha.

The type of soil in the swamps in question is heavy clay, which is admirably suited for the growing of rice. The vegetation of this area is partly forest (*Erythrina glauca*, *Triplaris surinamensis*, *Pterocarpus officinalis*, *Tabebuia insignis*-group) and partly a grass-like vegetation (*Cyperus giganteus*, *Cyperus articulatus*, *Typha angustifolia*, *Fuirena* spp.).

In order to make it possible to study the problems connected with the reclamation of these swamps and with mechanical rice cultivation, a start was made at the end of 1949 with the making of an experimental polder (Prins Bernhard Polder) in Nickerie.

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Quite soon it became apparent here that in mechanical rice cultivation weed control forms one of the principal problems. This is to be expected since the sown rice and the weed seeds have the same chance of developing, in contrast to the transplanting method in which the rice has a good start on the weeds.

After some three years enormous infestation of the fields by weeds (mainly grasses) occurred, which led to yield depression. A similar infestation was also observed on other farms which had adopted direct sowing of the rice some years previously.

Therefore, for the success of mechanical rice cultivation successful control of the weeds is a prerequisite. For this it will first of all be necessary to know the weed flora and the properties of the various plants.

In connection with the above the paragraph on 'Control' refers principally to the more or less mechanized farms. Only the most important results will be given.

THE WEED FLORA

The composition of the weed flora in the rice fields will depend on the following factors:

(1) Length of time that the soil has been under cultivation. In the first years after reclamation a fairly large number of types of plants of the original vegetation will still be present.

(2) Properties of the soil; possibilities of irrigation and drainage. The texture of the soil will also influence the moisture conditions.

(3) Methods of cultivation. Besides tilling, the method of planting and sowing is of particular importance.

To determine the composition of this weed flora botanical records were kept in a large number of rice fields. In these all the species of plants occurring were noted, and which plants predominated. Notes were also made regarding the moisture conditions, tilling, method of planting and sowing, *etc.* This investigation revealed the following as the most important weeds:

Grasses

Ischaemum rugosum Salisb.
Echinochloa colonum (L) Link.
Echinochloa crus-pavonis (H.B.K.) Schult.
Leptochloa scabra Nees
Luziola spruceana Benth.
Leersia hexandra Sw.
Panicum chloroticum Nees
Hymenachne amplexicaulis (Rudge) Nees

Cyperaceae

Fimbristylis miliacea Vahl
Torulinium ferax Urb.
Cyperus giganteus Vahl
Cyperus articulatus L.
Eleocharis interstincta R. et Sch.
Eleocharis mutata R. et Sch.

Other weeds

Cannaceae	:	*Canna glauca* L.
Marantaceae	:	*Thalia trichocalyx.*
Papilionaceae	:	*Aeschynomene sensitiva* Sw.
		Sesbania exasperata H.B.K.
Oenotheraceae	:	*Jussieua affinis* DC.
		Jussieua erecta L.
		Jussieua leptocarpa Nutt.
		Jussieua leptocarpa Nutt. var. *aluligera* (Miq.) Jonk.
Campanulaceae	:	*Sphaenoclea zeylanica* Gaertn.
Euphorbiaceae	:	*Caperonia palustris* (L.) St. Hil.
Solanaceae	:	*Physalis angulata* L.
Menyanthaceae	:	*Nymphoides humboldtianum* (H.B.K.) O.K.
Nymphaeaceae	:	*Nymphaea amazonum* Mart. et Zucc.
Alismataceae	:	*Lophotocarpus guyanensis* var. *echinocarpa* (Mart.) Buch.
Butomaceae	:	*Hydrocleys nymphoides* (Willd.) Buch.

In mechanized rice cultivation (sowing) the grasses form the chief problem. If precautionary measures are not taken in time they may increase in a few years to such an extent that yield depressions of 50 per cent and more are by no means exceptional.

Of the grasses listed in the table above, the first four occur most, and of these, *Ischaemum rugosum* is the most dangerous. The fields can be infected in a very short time by this species which in its early stage greatly resembles rice, as does *Echinochloa colonum*. By their growth habit these two grasses can completely oust the rice.

Although *Echinochloa crus-pavonis* and *Leptochloa scabra* can infest the rice fields to a serious extent, these grasses are less aggressive, owing to their vertical growth, and are consequently less dangerous.

The remaining grasses given in the table seldom occur to a considerable extent, apart from *Hymenachne amplexicaulis*, which occasionally predominates in some rice fields. It should be stated, however, that *Luziola spruceana* can cause considerable trouble, as the irrigation and drainage canals can be entirely choked up by this grass.

In the system of rice growing as practised by the small scale farmer (transplanting method), the grasses are of minor importance. To a high degree this is a result of the fact that these fields are grazed after the rice harvest, and this results in annual grasses such as *Ischaemum rugosum*, *Echinochloa colonum*, *Echinochloa crus-pavonis* and *Leptochloa scabra* having little chance to spread.

Of the Cyperaceous weed group, *Fimbristylis miliacea* proved to be present in all rice fields. If there is a shortage of irrigation water this plant can become dominant, as a result of which the stand and production of the rice can greatly deteriorate.

Cyperus giganteus occurs only in fields which have been newly reclaimed, disappearing of its own accord after a few years. *Torulinium ferax* is mostly found in groups. The two *Eleocharis* spp. and *Cyperus articulatus* are found in particular on small scale farms. Sometimes these cyperaceous weeds can be a real nuisance, for with superficial tillage they can be spread considerably by their root parts.

The group of other weeds occurs in both mechanized and non-mechanized agriculture, although the degree of incidence is considerably greater in the case of mechanized rice cultivation.

Canna glauca and *Thalia trichocalyx* may seriously infect the rice fields, particularly in the first years after reclamation, and thus cause enormous yield depressions. Moreover, the large leaf masses of these plants will clog the combines again and again, so that the daily capacity of the latter will be far too low.

Additional wear and tear and the breaking of certain parts are also a consequence of fields infested in this way. This also applies to *Aeschynomene sensitiva*, *Sesbania exasperata* and the *Jussieua* spp., which may sometimes occur in large quantities. At the time of paddy harvesting these plants are somewhat woody.

Although *Caperonia palustris* and *Physalis angulata* are encountered fairly regularly in the rice fields, they never occur in large quantities. This is not the case with *Sphaenoclea zeylanica*, which can rapidly spread, owing to its enormous seed production, and can then be a real nuisance.

If the rice is sown in water (10–15 cm in depth) to control the grasses, algae and floating aquatic plants such as *Nymphoides humboldtianum*, *Nymphaea amazonum*, *Lophotocarpus guyanensis* var. *echinocarpa* and *Hydrocleys nymphoides* get the chance to predominate.

It should finally be noted that nearly all of the plants which belong to the weed flora in rice already occur in the original woody or herbaceous swamp vegetation of these areas. An exception to this is formed by the grasses *Ischaemum rugosum*, *Echinochloa colonum*, *Echinochloa crus-pavonis* and *Leptochloa scabra*, which have come from elsewhere and found their way into the fields after the soil was brought under cultivation.

Control

If we wish to control weeds in the cultivated crop, we should first investigate the way in which new weed seeds enter our fields. This entry may be effected by:

(*a*) wind borne seed,
(*b*) water borne seed,
(*c*) seed carried by birds and animals,
(*d*) seed transported by implements,
(*e*) the use of impure seed,
(*f*) direct sowing of weed seeds from the previous planting and from surrounding embankments and windrows.

To limit as much as possible the damage which the weeds cause, we have three different methods at our disposal, viz.:

(1) Prevention of infection by weed seeds from elsewhere.
(2) Cultivation measures.
(3) Chemical control of weeds.

(1) *Prevention of Infection*—Hardly any steps can be taken against (*a*), (*b*) and (*c*) above, but this is not so in the case of (*d*), (*e*) and (*f*), however.

To obtain some insight into the spreading possibilities of the most important grasses the number of seeds per flowering stem was counted. On an average, these numbers were as follows:

	Average
Echinochloa colonum	300
Echinochloa crus pavonis	1400
Ischaemum rugosum	60
Leptochloa scabra	5000

It can clearly be seen from the above table that *Leptochloa scabra* produces very many seeds, and that after infection of a rice field by this grass, rapid spreading is to be expected. This has already proved to be the case in the Wageningen scheme, where this grass was present in large quantities in fields which had just been reclaimed. Here contamination was caused by implements.

Although *Ischaemum rugosum* produces relatively little seed, this grass can, nevertheless, spread very quickly. In practice it has proved that this must to a considerable extent be ascribed to the use of impure seed.

In order to keep the embankments clean they were planted in the Wageningen scheme with Bermuda grass (*Cynodon dactylon*). This grass forms a dense, close mat, in which weeds have little chance to establish themselves. To date this measure has proved most successful.

By using clean implements and pure seed, and by keeping the embankments and any windrows clean, infection by weed seeds from elsewhere can be prevented. Once the fields are contaminated it will cost considerable trouble and money to restore them to a decent state. It is therefore definitely worth while to pay sufficient attention to the above points; this, unfortunately, is not done in many cases.

(2) *Cultivation measures*—When the paddy is harvested, most of the weeds occurring in the crop have already formed their seeds and often have even dropped them on the ground. Cultivation measures such as ploughing and harrowing are carried out not only to obtain a suitable seed bed for the paddy, but also to destroy the weeds. If it is desired to obtain the greatest advantage from this tilling, it is essential to be conversant to some extent with the behaviour of the various weed seeds (germination conditions, dormancy periods, duration of germination, *etc*). A start has already been made with this investigation and the following examples may be quoted.

Jussieua spp. and *Fimbristylis miliacea* have no dormancy period and, moreover, germinate very quickly if the soil is moist enough. Very shallow tilling after the harvest (superficial disk harrowing) will be favourable for the germination of these seeds. After about two weeks a fairly large proportion of the seed will have come up. Subsequent tillage will destroy the seedlings.

Seed of *Canna glauca* has a very hard coat, as a result of which it absorbs water very slowly; considerable time may therefore elapse before this seed germinates. In the ground it may retain its germination capacity for a very long period of time, but if the seed is somewhat damaged on the outside, it absorbs water more quickly and thus germinates fairly rapidly. In general, therefore, it will be impossible to put off sowing of the second crop until this type of seed has germinated. Oilseeds, too, generally have a long germination period.

A third group of seeds is formed by those with a dormancy period. *Ischaemum rugosum*, for instance, has a dormancy period, as can be seen from *Figure 1*.

Seeds with a long dormancy period, as in the case of the previous group, cannot be destroyed by cultivation measures such as harrowing or ploughing before the crop is sown. As a result of ploughing, these seeds are sometimes buried deep in the ground, and consequently germination is prevented, but in later tillage these layers of soil frequently come to the surface, and the chance of germination occurs again.

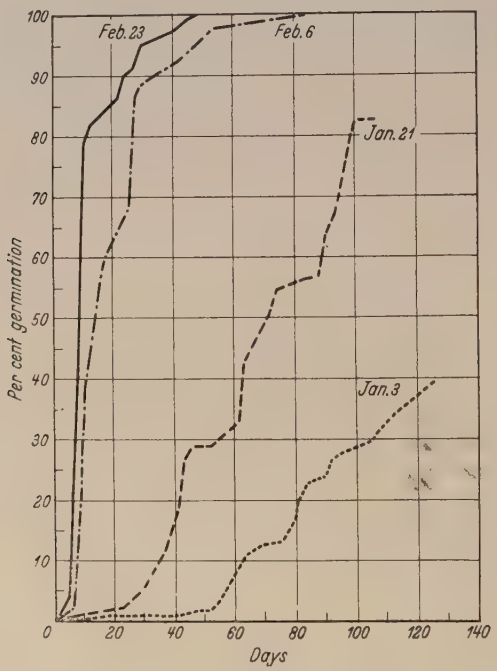

Figure 1. Germination of Ischaemum rugosum. *Seeds were harvested on 2 January 1953. Data at end of curves indicate days on which germination tests were started*

If there is insufficient moisture present in the ground to let the seeds germinate, tillage serves little purpose, at least as far as weed control is concerned. If there is not enough time available to wait for a rain-shower, it is advisable, in such cases, to irrigate the field, possibly after shallow stubble ploughing. After the water has been drained away many of the more rapidly germinating weed seeds will soon germinate, after which the young weed plants can be destroyed by ploughing or disk harrowing.

However, the opportunity of irrigating the fields and getting them dry again soon enough for cultivation does not always occur and, moreover, by no means all of the weed seeds are destroyed by this treatment, since on each occasion after working the soil a new layer containing seeds which still have a germinating capacity comes to the surface.

Another method of cultivation used to control the weeds is the sowing of paddy in a layer of water about 10 to 15 cm in depth, which must remain on the field without interruption. In this way it has proved possible to efficiently control grasses such as *Echinochloa colonum*, *Echinochloa crus-pavonis*, *Ischaemum rugosum* and *Leptochloa scabra*. *Fimbristylis miliacea*, one of the

most troublesome weeds in badly irrigated fields, can also be suppressed by a layer of water. This can clearly be seen from the following figures, which were obtained from trials in tanks (cross-section 0·096 m^2):

	Number of flowering stems of Fimbristylis miliacea			
	cm	cm	cm	cm
Depth of water	5	10	15	20
After 2 months	40	3	0	0
After 4 months	166	67	0	0

However, the paddy will grow through such a layer of water, although the germinating and growing capacity may be highly dependent on the variety. Pre-germinated seed is mostly more favourable than seed not so treated. The seed must have germinated up to the point when the seed is just about to break through the glume. Longer germination entails the risk of the seed being damaged in mechanical sowing. This sowing can be carried out in two different ways, viz. (*a*) sowing on the dry ground and immediately flooding the field with a layer of water 10 -15 cm in depth, or (*b*) covering the field with 10–15 cm of water and then sowing in the water. A prerequisite of this method of cultivation is that one must have sufficiently flat fields and a good command of water.

Various weeds nevertheless grow through a layer of water (*Sphaenoclea, Canna, etc*), so these must be controlled later in another way, namely by chemical weed control.

(3) *Chemical Control of Weeds*—In the past two to three years the Foundation for Mechanical Agriculture and the Development Fund have carried out various extensive tests, both with pre-emergence and post-emergence application, on chemical control in the Prins Bernhard Polder in Suriname. The substances used included: DNOC, DNBP, PCP, Na arsenite, 2, 4-D, MCPA, 2, 4, 5–T and brushkillers (mixtures of 2, 4–D and 2, 4, 5–T). In a pre-emergence treatment no success was recorded with any of the agents, nor in a post-emergence treatment with the first four agents listed above. On the other hand, favourable results were achieved with the last four agents (all growth-regulating substances) in a post-emergence treatment.

The following conclusions regarding spraying time and agents can be drawn from these tests.

(*i*) *The best time for spraying* lies between five and eight weeks after the paddy has come up. Before this time not all the weeds have germinated and appeared above the surface of the water, so that new plants would again appear later. The best results are obtained if, just before spraying, the depth of water is reduced to a few centimetres, thus enabling as many weeds as possible to show above the water and come into contact with the spraying liquid. A shallow layer of water on the field is to be preferred to an entirely dry field if one has to drive a tractor through the plantation. Under these conditions the wheels wash clean to a better degree and consequently less tractive power is required (this applies at least to heavy clay soils which are difficult to drain).

If spraying is carried out after eight or nine weeks then there is the danger that the paddy will, even at that stage, become too susceptible to the growth-regulating substances and suffer a loss in yield.

(*ii*) *Agents*—The weeds were more satisfactorily controlled and the paddy

less damaged by 2, 4–D, MCPA and the brushkillers, in that order; the price of the agents proved to be higher in that order, too.

The most suitable quantities for our purposes, expressed in kg acid equivalent per hectare, are 1·6–1·8 kg for 2, 4–D, about 1·8 kg for MCPA and about 0·3 to 0·6 kg 2, 4, 5–T and 0·6 kg 2, 4–D for the brushkillers. The agent, 2, 4, 5–T is still too expensive.

The susceptibility of the various weeds to these agents is given in *Table 1*, from which it will also be found that most of the weeds occurring in the wet rice fields, with the exception of the grasses, can be controlled by the brushkillers. *Sphaenoclea zeylanica* merely experiences a retardation in growth when treated with the normal quantity of brushkiller, but can, however, be controlled with about four-thirds as large a quantity.

Table 1

	2, 4–D *about* 1·7 kg *acid equiv.*/ha	MCPA *about* 1·8 kg *acid equiv.*/ha	*Brushkillers* 0·3–0·6 kg 2, 4, 5–T 0·6 kg 2, 4–D *acid equiv.*/ha
Canna glauca	+++	+++	+++
Jussieua spp.	+++	+++	+++
Floating aquatic plants	+++	+++	+++
Physalis angulata	+++	+++	+++
Fimbristylis miliacea	+++	+++	+++
Cyperus articulatus	++	+++	+++
Caperonia palustris	++	+++	+++
Cyperus giganteus			+++
Sesbania exasperata	++	++	+++
Thalia trichocalyx	+	+++	+++
Aeschynomene sensitiva	+	+	+++
Sphaenoclea zeylanica	+	+	++

+++ = Dead. ++ = Retarded in growth. + = Not affected.

All the tests were made with the Rexoro variety of rice. Mostly small scale preliminary tests were instituted with three parallel rows, the size of the plots being about 40–100 m². Larger scale practical trials were then carried out on the agents yielding the best results, with three parallel rows and plot-areas of about 1/3–1/2 ha, which were harvested with the combine. On these large plots spraying was carried out with a boom sprayer of 10 m boom length, mounted on a Farmall Super C wheeled tractor, which was driven through the wet fields. Yield depression by damage caused by this tractor could not be established, in contrast to damage caused by a caterpillar tractor (yield depression of about 100–200 kg/ha). In most cases about 100 l. of spray liquid were atomized per hectare. Differences in concentration of the spray liquid yielded no difference in result, provided that the required quantity of kilogramme acid equivalent per hectare was used.

In contaminated fields spraying led to yield increases of 800 to 900 kg of rice per hectare. In fairly clean fields no yield increases could be established with 2, 4–D and MCPA, whereas in these cases a field treated with brushkiller gave a yield increase of 194 kg/ha, compared with the untreated fields.

It will be further investigated whether these brushkillers exercise a favourable influence on the paddy.

SUMMARY AND CONCLUSIONS

The rice production of Suriname is derived for the greater part from small family-sized farms. On these farms rice is cultivated by the transplanting method. In recent years, however, more and more attention has been paid to mechanization and in 1949 an experimental polder was made for the purposes of studying the problems connected with mechanical rice cultivation.

The consequence of direct sowing of the rice was an enormous contamination of the fields by grasses and broadleaved weeds. These sometimes caused large yield depressions (50 per cent and more). Weed control proved to be one of the chief problems of mechanical rice cultivation.

By means of a large number of botanical records a picture could be obtained of the most important rice weeds.

Field trials were used to discover the way in which these weeds can be controlled, and the most important conclusions are :

(1) Most rice weeds are already present in the original woody or herbaceous swamp vegetation of these areas. An exception to this is formed by the grasses *Echinochloa colonum*, *Echinochloa crus-pavonis*, *Ischaemum rugosum* and *Leptochloa scabra*, which come from elsewhere.

(2) The above grasses may be the cause of large yield depressions in mechanical agriculture. In small scale farming (transplanting method) *Fimbristylis miliacea* may be a troublesome weed if there is a shortage of irrigation water.

(3) By sowing the rice in water (depth 10–15 cm) control of these grasses, and of *Fimbristylis miliacea*, proved feasible, but the growth of algae and floating aquatic plants was increased.

(4) Weed infections can be partly prevented by the use of clean implements and well-cleaned seed. In this connection it is also of great importance to keep the embankments clean. It will be possible to destroy part of the weeds by ploughing and harrowing during the dry fallow.

(5) It proved possible to control most of the broadleaved weeds by the use of chemical agents. This can best be done five to eight weeks after the paddy has come up. Of the agents used, the brushkillers were the most satisfactory, followed by MCPA and then 2, 4–D. By the use of these yield increases of 200–900 kg/ha were obtained.

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Studies in the Mineral Nutrition of Sugar Cane in British Guiana

I—A Preliminary Survey of the Nutrient Status of Sugar Cane using Rapid Fresh Tissue Tests

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INTRODUCTION

Rapid soil tests based on extraction with the Morgan (1939) reagent (sodium acetate + acetic acid) have been adapted for plant analysis particularly by Nicholas and Jones (1944), Bray (1945), Carolus (1936, 1938) and others. The Long Ashton workers have refined the techniques and have successfully used the methods for nutritional surveys in west and south-west England. The writer Evans (1952) found the methods of value in determining the nutrient status of cacao.

At the time this work was carried out there were no records of similar methods having been used for sugar cane but recently Bedsole and Breggar (1953) have carried out an investigation on the relationship of rapid chemical analyses of soil and fresh sugar cane tissue to growth and yield. In their work the fresh material was disintegrated with 0·5N acetic acid in a Waring blender for periods up to 6 min: parallel samples of tissue were dried and the results expressed as per cent of the dry tissue. From their results it would appear that potassium was fairly completely extracted by this technique but that only about half the phosphate was extracted.

METHODS

A sample of the elongating leaf sheaths (sheaths of leaves Nos. 3–6 counting the rolled spindle as No. 1) as used by Clements (1953) for his log were collected from five shoots selected at random in each field. The sheaths were split lengthwise into strips 5 mm wide and the middle portion of each strip cut into pieces 2 mm wide by means of a stainless steel scalpel.

The chopped-up pieces of sheath were extracted with Morgan's reagent (sodium acetate+acetic acid at pH 4·8) for exactly 15 min at the rate of 10 cc Morgan reagent for each gram of fresh tissue, and the extracting liquid then decanted off. On this extract the following elements were determined—potassium, calcium, magnesium, manganese, chlorides, sulphates, phosphates.

A parallel sample of the chopped-up sheath material was treated with conc. HCl and diluted with glass distilled water after 15 min. This extract was used for the determination of iron, copper, zinc, and molybdenum.

Most of the Morgan extract analyses were carried out according to the technique of Nicholas and Jones (1944)—the concentration of the elements being estimated colorimetrically or turbidimetrically with a Unicam diffraction-grating spectro-photometer.

Manganese was determined colorimetrically with formaldoxime, iron with thioglycollic acid, copper with sodium-diethyl-dithio-carbamate using ethylene-diamine-tetra-acetic-acid to prevent interference by other metals; zinc by dibetanaphthyl-thiocarbazone and molybdenum by isopropyl ether extraction of the thiocyanate. The quantity of molybdenum was too low for estimation by the prepared zinc-sulphate-potassium-ethyl-xanthate paper used successfully by the writer for cacao leaf tissue. A rough test for zinc can be carried out by splitting the cane through the centre and flooding the cut surface with a solution of dithizone in chloroform—a pink coloration develops at the nodes when zinc is present (Shaw, 1952). In the case of cane grown in aerated culture solution in the absence of zinc no red colour developed with this reagent.

Since no critical values were available for rapid tissue tests on sugar cane, the procedure generally adopted was to compare the analysis of cane which was not thriving with cane of the same variety and age showing the best growth. Additionally some full chemical analyses on samples of the same tissue were made in order to relate the amounts extracted by Morgan's reagent to the total content.

RESULTS

Nitrogen

In the rapid tissue tests nitrate or ammonia nitrogen are generally taken as indicators of nitrogen status. In sugar cane the amount of these simple forms of nitrogen is too low to be of value in estimating nitrogen status. Assuming the total nitrogen content of the leaves as used by Clements to reflect the nitrogen status, good correlations were obtained between this figure and (*a*) total nitrogen per cent fresh weight of chopped-up sheath tissue, (*b*) total nitrogen determined on fresh leaf discs punched from the leaves.

As neither of these methods can be regarded as rapid, it was decided that visual observation of foliage colour and anthocyanin pigmentation of the sheaths and dewlap, could, with practice, be satisfactorily used for estimating the nitrogen status when nitrogen was seriously deficient; full quantitative analysis would be preferable for more quantitative work.

Potassium

A good correlation was obtained between the potassium content of the Morgan extract and the total potassium expressed on the basis of sugar-free dry matter of the elongating leaf-sheaths (see *Figure 1*). With a total potassium content of 2·25 per cent K in the sugar-free dry matter of the leaf sheath, the corresponding potassium content of the Morgan extract was about 175 p.p.m. Several hundred sheath samples were assayed by the rapid method—the values ranged from 30 p.p.m. in the Morgan extract to over 300 p.p.m. It was apparent that considerable differences existed even between the frontland clay soils along the sugar belt.

The lowest values 30–70 p.p.m. were found in the Tuschen, Zeeburg and DeKinderen sections of Uitvlugt estate. As plants grown without potash in aerated nutrient culture assayed about 30 p.p.m. by the same technique, it was quite apparent that some of the fields were suffering from acute potash deficiency, and indeed visual symptoms of potassium deficiency were to be

seen in some of the fields in Tuschen assaying 30–40 p.p.m. of potassium in the Morgan extract. Many of the fields in the Uitvlugt section of the estate showed 160–200 p.p.m. of potassium at the same time.

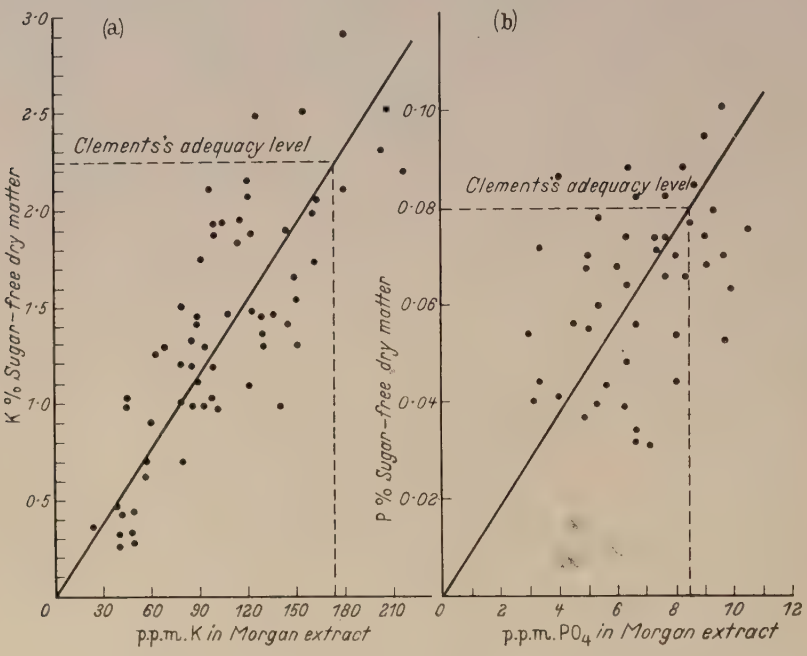

Figure 1. *(a) Correlation between potassium content of sugar-free dry matter of leaf sheath tissue and potassium extracted by Morgan's reagent. (b) Similar diagram for phosphate*

At Wales estate, although values as low as those obtained in some sections of Uitvlugt did not occur, there were several fields assaying 60–80 p.p.m. of potassium.

At Houston estate the potassium values were considerably higher, being generally in the range 150–300 p.p.m. On the East Coast estates values ranged from 120–200 p.p.m. generally but levels at Lusignan estate were generally lower with values from 70–90 p.p.m. of frequent occurrence. At Enmore estate about 50 per cent of the values were between 100 and 150 p.p.m. and 50 per cent were between 150 and 220 p.p.m.

Fewer samples were taken from the Berbice estates, but no samples below 150 p.p.m. were found—the range being 150–250 p.p.m. Assuming that adequacy of potassium meant assays of 150–180 p.p.m., as would be expected from the relationship between the rapid tissue tests and total potassium, it appeared that varying degrees of potassium deficiency occurred even on frontland clay areas on the coast, particularly on the East and West Coast Demerara estates. The same tests indicated adequacy of potassium on the Berbice estates. This conclusion was contrary to the generally accepted views on the potassium status of the frontland clays which were held to be adequately supplied: but varying degrees of potassium deficiency have since been substantiated by field trials.

Phosphorus

Phosphorus was poorly extracted by the Morgan reagent and the correlation between phosphorus in the extract and the total phosphorus per cent of the sugar-free dry matter of the leaf sheath was much less close than was the case with potash. Values of phosphorus were mostly in the range 4–12 p.p.m. PO_4 in the Morgan extract. Sheath samples from cane plants grown in aerated culture solution in the absence of phosphorus assayed 2·5–3·0 p.p.m. by the same technique. A phosphorus content of 8–9 p.p.m. PO_4 in the extract corresponded approximately to total P of 0·080 per cent in the sugar-free dry matter of the leaf sheath. The latter figure has been accepted by CLEMENTS (1953) as adequate. Of several hundred sheath samples assayed very few samples exceeded the figure provisionally accepted as representing adequacy, *viz* 8–9 p.p.m. PO_4 in the Morgan extract.

Consistently low values 4–5 p.p.m. occurred in many of the Berbice estate samples. Certain sections of Uitvlugt estate (particularly Zeeburg and de Willem sections), and of Wales estate (particularly Potosi section) were as low as the Berbice estates with values of 5–6 p.p.m. Most of the East Coast estates showed values of 5–7 p.p.m. with occasional values of 9–11 p.p.m.

In order to extract more of the phosphorus, a modification of procedure was tried in which the tissue was macerated with Morgan's solution in a high speed blender for exactly 3 min. Values for PO_4 by this method ranged between 10 and 25 p.p.m., the value corresponding to 0·080 per cent P on the dry matter being approximately 18–20 p.p.m. PO_4. The relative values by this method, however, agreed, though at a higher level, with those obtained by the usual procedure. The general indications were that the Berbice estates and parts of all the other estates investigated were likely to have inadequate phosphorus. This conclusion has also been substantially confirmed by fertilizer responses.

Calcium

Calcium showed larger variations than most elements. The differences in calcium content are probably exaggerated by this method since, when the calcium content is very low, the precipitation of the oxalate is rather delayed. The calcium content in the Morgan extract of material grown in calcium-free nutrient solution and showing deficiency symptoms was 5 p.p.m. whereas completely nourished plants showed 40–50 p.p.m. Ca in the extract. Samples from representative fields from the estates were within the range 8–60 p.p.m., the majority being in the range 12–25 p.p.m.

Several hundred analyses were made with the Waring blender technique as described for phosphorus. Approximately twice as much calcium was extracted by this method as by the normal one. The average values for the bulk of the samples were in the range 30–40 p.p.m. Since the calcium content of the Morgan extract frequently approached the value obtained for the calcium deficient material grown in calcium-free aerated nutrient culture particularly in samples from parts of Uitvlugt estate, Wales estate, La Bonne Intention estate and Lusignan estate, it appeared that actual calcium starvation symptoms would be expected to occur. Acute calcium

starvation symptoms were later seen in these areas and occur particularly in badly drained fields where root development is poor. The growing point was particularly affected and new leaves were malformed, chlorotic, and greatly reduced in size (*Figure 2*).

(*a*) (*b*) (*c*)

Figure 2. (*a*) *General appearance of part of 90 acre block at La Bonne Intention sugar estate showing cane suffering from calcium deficiency:* (*b*) *and* (*c*) *showing cessation of terminal growth and abnormal malformed young leaves*

Adequate calcium has been found to be associated with values of 25–30 p.p.m. Ca in the Morgan extract by the ordinary 15 min soak method and 40–50 p.p.m. by the Waring blender 3 min maceration technique.

Magnesium

Magnesium did not show such wide variations, the range being from 10–25 p.p.m. by the 15 min extraction and 20–50 p.p.m. by the 3 min maceration method. The magnesium content of extracts of sheath material grown in magnesium-free nutrient solution and showing visual symptoms of magnesium deficiency was exceedingly low—of the order of 0·5 p.p.m. However, the magnesium requirement for optimum growth is much higher than this. It appeared unlikely from the wide range of samples analysed that magnesium could be deficient—and it was more likely to be present in excess on occasions.

Manganese

Nicholas and his colleagues use the tetra-base (Tetra-methyl-diamino-diphenyl-methane) method for manganese when present in deficient amounts and recommend the formaldoxime method for excess quantities of

manganese. The latter method can, however, be made fairly sensitive and in practice may be used for routine manganese estimation; the former method being then reserved for samples which fail to give a colour reaction with formaldoxime only. Actually no samples were found which did not give a strong manganese colour reaction with formaldoxime even in the extract with the Morgan reagent. The manganese content varies from 1 to 4 p.p.m. Mn in the Morgan extract : sheaths of cane plants grown in the absence of manganese and showing wild manganese deficiency symptoms did not give a reaction when extracted with Morgan's reagent. It was concluded, therefore, that the manganese values found were well above minimal requirements.

Iron

Iron was not satisfactorily extracted by the Morgan reagent and although a few positive iron tests were obtained, the majority were negative. Iron was accordingly determined on the HCl extract; the range of values found was 2–5 p.p.m. in this extract. Iron deficiency symptoms have only been seen in small localized patches on dam beds following the dumping of large quantities of filter mud. It was concluded that the values for iron in the HCl extract were adequate.

Copper, Zinc and Molybdenum

A limited number of the HCl extracts of the fresh sheath tissue were examined for these micro-nutrients.

Copper determinations were quantitative, using 20 cc of the HCl extract: the total copper content of this quantity of HCl extract varied from 1·0 to 3·5 micrograms. Zinc determinations were qualitative only, and it was established that the molybdenum content was very low and that the values were below 0·02 p.p.m. in the HCl extract. No conclusions could be drawn on the status of these micronutrients from the rapid tissue tests, other than that the concentration of molybdenum appeared to be so low as to require full investigation. Subsequent to this investigation field deficiency symptoms of molybdenum have been seen. In fact the status of these elements as well as boron have been investigated by means of accurate analysis of the total content in the leaf dry matter.

Sulphates and Chlorides

No information was available as to the normal concentration of sulphates and chlorides extracted by Morgan's extracting solution. These anions were determined for comparative purposes, particularly in comparing unthrifty cane with healthy cane of the same variety and age. No correlations between the concentration of these anions and the growth of the cane could be established in this preliminary survey. Chloride in the Morgan extract varied from 10–175 p.p.m. It may be considered as normal under British Guiana conditions to have 20–80 p.p.m. chloride in the extract—in that the majority of the samples fell within this range; samples containing over 150 p.p.m. of chloride occurred in restricted localities including certain frontland areas of Houston estate, and the East Coast estates, and areas of Rose Hall estate and Port Mourant estate where chloride contents of 150–225 p.p.m. in the Morgan extract occurred.

The range of concentration of the sulphate ion in the Morgan extract was about the same as that of chloride, 50–175 p.p.m., but the average value was somewhat higher, *viz* 50–100 p.p.m. As healthy cane plants grown in complete nutrient solutions contained from 80–120 p.p.m. of SO_4 in the Morgan extract, it is considered that the values found in the survey do not call for comment.

MINERAL TOXICITIES

Aluminium

Most of the cane plants showing stunted growth seen during the course of this survey occurred in pegassy areas. Apart from showing relatively low phosphate content, the rapid tissue tests alone gave no indication as to the cause of the poor growth of these plants. The root system of the plants, however, showed the typical coralloid roots resulting from aluminium toxicity (*Figure 3*). The inference that aluminium toxicity was indeed the

Figure 3. Showing effect of aluminium toxicity on root development. The stunting of the main root and laterals results in a coralloid appearance of the roots

cause of the stunted growth was supported by the high water-soluble aluminium content of the soils where this condition occurred and by the staining of the outer tissues of the roots when treated with haematoxylin alone according to the technique of WRIGHT and DONAHUE (1953). There is considerable evidence that when pegasse overlies bauxitic clay, soluble complexes or chelates of aluminium with the organic constituents of the peat occur. Flood fallowing—even where practicable—on such pegasse overlying aluminium-containing clays does not lead to any leaching out of the aluminium nor to any improvement of cane growth, indeed, the contrary

is often the case since generation of water-soluble aluminium compounds continues. Roots do not show the coralloid, stunted growth in the clay in the absence of the peat, and one method which has been used to overcome this aluminium toxicity is to bull-doze the pegasse off the surface and plough and fertilize the underlying clay. Roots which are protected from the pegasse whilst growing downwards (such as by growing through pieces of rotting sugar cane) proliferate in the clay below. Cane may also be successfully grown in such areas with fairly heavy dressings of lime and phosphate. The crops improve with cultivation since in due course the peaty materials which bring excessive aluminium into solution become depleted by oxidization. Probably one of the most economical means of treating such land is to form fairly deep furrows so that the cuttings are planted on or as near as possible to the clay applying fairly liberal dressings of lime and phosphate at the bottom of the furrow. Filter mud or filter cake is also of great benefit.

Magnesium

In the pegasse areas at the back of Ogle estate stunted cane occurred which was not caused by aluminium toxicity. Not only did the roots show none of the coralloid features of aluminium toxicity, but little or no water-soluble aluminium occurred in this soil. The older leaves of the cane showed a rusty appearance and the leaves were characterized by a high content of nitrogen (often up to 3·6 per cent N), and very high magnesium (up to 0·6 per cent Mg). The high content of magnesium was apparently responsible for the stunted growth and the magnesium is believed to have been due to saline water from the lower reaches of the Demerara river having percolated through pervious sand layers and become concentrated in this low-lying pegasse area. By improving the drainage, applying moderate dosages of limestone, potash and phosphate, and selecting varieties which are the most tolerant to these conditions (B.37161, B.4362, B.47379 and Co.419), promising results are being obtained.

Iron

During an intensive search for ratoon stunting disease in the colony wherein many hundreds of canes were split open, cases where the lower nodes of the cane were discoloured in varying degrees from a dirty orange colour to deep grey were frequently seen. These symptoms did not occur in the aluminium toxic pegassy soils to any great extent, but were more frequent in the frontland clay and were prevalent at Rose Hall estate and to varying degrees in the other Berbice estates. These grey nodes invariably give an intense reaction for iron; while no cane has yet been tested in British Guiana which does not give a markedly positive iron test at the nodes, the grey-noded canes give a far more intense reaction than canes with the usual cream-coloured nodes, and the pattern of the iron reaction falls exactly on that of the grey discoloration. Moreover, the incidence of these symptoms are largely seasonal and occur in frontland clays during periods of heavy rains. It is believed that the reducing conditions which occur during such periods bring considerable amounts of iron into solution in the soluble ferrous form and this is taken up by the cane and heavily deposited at the

nodes. This deposition obviously interferes with the free movement of water and solutes since canes with grey nodes are invariably stunted: and phosphate in particular is immobilized. Improved drainage, liming and fairly liberal phosphate applications appear to be the best corrective measures against iron toxicity.

Manganese

A symptom which is frequently seen in wet weather and to which the variety B.34104 is particularly prone, consists of a pale interveinal chlorosis of the youngest leaves, almost identical in appearance to a mild iron deficiency. It does not, however, respond to iron nor to painting or injection by any other micro-nutrient. Leaves showing these symptoms, however, invariably contain a high manganese content—well over 350 p.p.m. in the dry matter. It does not appear that the symptoms are of any economic significance, for the symptoms are reduced as the leaves mature and yields do not appear to be affected.

DISCUSSION AND SUMMARY OF RESULTS

By the use of rapid tissue tests on comparable material it proved possible to obtain an approximate picture of the general nutritional status of sugar cane on the different estates and soil types in British Guiana. The methods are only roughly quantitative in that the proportions of the various minerals removed by the extracting solution vary. By means of these tests together with visual diagnosis, it was possible to form the following broad picture of the most significant aspects of the nutritional status.

Potassium was likely to be inadequate in some areas of the East and West Coast Demerara. Phosphate was very low in many of the cane samples and particularly in the Berbice estate samples.

Calcium was sufficiently lacking to result in visual symptoms of calcium deficiency on some fields in the Demerara estates. Magnesium appeared to be plentiful in all districts. Certain samples contained a fairly high content of chloride. In the pegassy areas, aluminium toxicity was shown to be responsible for considerable stunting of the cane: in one area magnesium toxicity was responsible for poor growth. Of the micro-nutrients, iron and manganese were present in high concentration, copper and zinc were present but it was not possible from these tests to determine whether the amounts were adequate, deficient or excessive; molybdenum was present in very low concentrations. Field deficiency symptoms of molybdenum which were later seen will be described in a subsequent paper in this series.

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The Rapid Analysis of Sugar Cane Stalks for the Determination of Cane Quality

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INTRODUCTION

When modern sugar cane breeding was intensified in most sugar cane growing countries in the late 1920s and early 1930s it became necessary to evolve a rapid method of evaluating the seedlings produced. The hand refractometer proved a useful tool in many countries where a normal ripening season for cane could be expected. This instrument, of course, only measures the refractive index of easily expressed juice from the cane, but this physical constant is intimately related to the dissolved solids, which, in mature cane are, in turn, closely related to the sucrose content.

For more accurate evaluation of selected seedlings, various types of shredders or laboratory mills have been used—the expressed juice and the residue or bagasse being separately analysed, the sucrose content of the original cane can then be easily calculated. The hand refractometer for determination of brix has been used in many countries also as a guide to when the cane is ripe for cutting: in other countries more elaborate methods of assessing cane quality have been employed.

In British Guiana the estates have relied to a considerable extent on refractometer brix values in the past, but the present authors and their colleagues showed that, as used under local conditions, this method was unreliable. R. A. Yates determined refractometer brix in several fields and compared the values so obtained with actual factory returns from the same fields. No correlation whatsoever was obtained between the two sets of data. There is little doubt that this result was due in great part to inadequate sampling methods, but it is equally certain that differences in the composition of the cane were partly responsible.

In a country like British Guiana, located within five degrees of the equator and therefore without marked extremes of temperature, with (in the cane-growing area) heavy clay soils and a water table permanently within a few feet of the surface, climatic conditions are unfavourable to high quality in the cane, but are on the contrary, highly favourable to vegetative growth. Unlike more favourably situated territories where climatic conditions bring about cessation of vegetative growth and full ripeness in the cane, maturation in British Guiana is more a function of weather conditions, of the age of the cane, of its previous nutrition, of the effectiveness or otherwise of the drainage facilities, of the presence or absence of considerable quantities of salt in the soil, and, of course, of the particular variety to ensure that the cane is cut at the peak of its sucrose content, and juice purity is therefore correspondingly of much greater importance than it is in several

other countries, particularly as the harvesting season extends over a period of about nine months of the year.

Extensive experimentation on possible means of improving juice quality, which was part of the authors' research programme, again necessitated a rapid and reliable method of evaluating cane quality.

Experiments were carried out with a cane shredder, but the slow rate of disintegration of the cane together with the necessity of duplicating the analyses on expressed juice and residue made the procedure tedious for the purpose envisaged. The method which is described in the present paper has been found rapid and reliable and to fulfil the requirements of a rapid method for maturity testing and other projects associated with cane quality.

EXPERIMENTAL PROCEDURE

Sampling

Several hundred analyses of canes and of whole stools were carried out to evolve a suitable sampling method for fields and for blocks of fields. Originally, on account of the variability of the cane under British Guiana conditions resulting from the heterogeneous population of stalks in many fields, whole stool samples were preferred; 6–10 stools taken at random composed the sample. Recently, CHINLOY and INNES (1954) established the fact that however high the variability, a sample of individual canes gave lower errors for an equal number of canes than stool samples. In fact, stool sampling required five to six times as many stalks as single cane sampling for comparable accuracy. An examination of our data confirmed this.

Chinloy and Innes (*loc. cit.*) found nine canes taken at random to be necessary for a 5 per cent accuracy. In British Guiana 14–20 canes were found necessary to give the same degree of accuracy. Accordingly, 20 canes from each field or block were randomly selected by a similar method to that described by Chinloy and Innes, which ensured that a sample free from bias was obtained (Appendix 3).

Analysis

The canes were sawn longitudinally from top to bottom through the centre by means of a mechanically operated circular saw, the sawdust or brei being directed downwards through a chute and collected in a container below. It is important that the teeth of the saw be sharp and somewhat splayed outwards so that there is no ' closing-in ' of the cane on the saw and no juice is lost, and the brei is relatively free from long fibres*. It was realized that this method of sampling the cane would not, on geometrical grounds, be expected to be representative of the whole cane. In *Figure 1*, in which the effect is exaggerated, it will be seen that the saw-cut *ABDE* utilizes proportionately more parenchymatous tissue and less rind than the true representative sample depicted by the sectors *ABC* and *CDE*. It was considered, however, that the sample taken would be highly correlated for different cane samples.

In order to see what magnitude of error was involved analysis of brei from a longitudinal cut through the centre of the canes was compared with that of brei obtained by cross-cuts of comparable canes at $\frac{1}{2}$ in. intervals. The mean composition of the brei from several dozen cane samples carried

*Specifications are given in Appendix 1.

out in Bookers Central Laboratory by G. T. Lines and by D. B. Richards, surprisingly showed no significant difference in the sucrose and reducing sugar content of brei taken by the two methods.

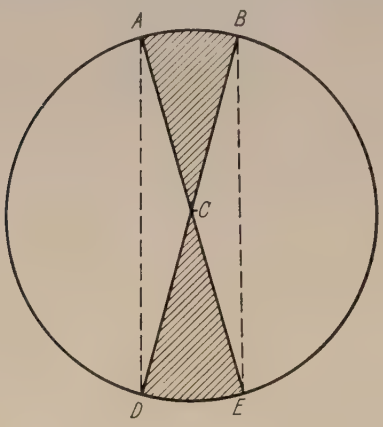

Figure 1

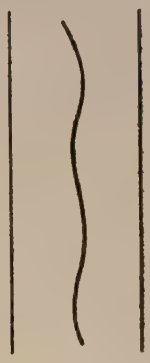

Figure 2

The probable explanation of this result is that the situation depicted in *Figure 1* does not, in fact, represent the course of the sawblade which in actual practice follows a wavy path down the centre of the stalk as depicted in *Figure 2* resulting in brei being formed from tissues on each side of the centre. This apparently counteracts most of the possible bias of the type shown in *Figure 1*. In actual fact, therefore, the brei collected by sawing the cane through the centre is truly representative of the whole cane.

The brei sample was intimately mixed and a representative sample of 52 g of the fresh material rapidly weighed out and placed in the container of a blender or macerator of the Waring type together with sufficient water to bring the volume to 500 cc (in practice 460–465 cc of water). Originally sucrose and reducing sugars per cent cane only were required and for this maceration was allowed to proceed for 3 min, stopped for 1 min during which time a salt-spoonful of Horne's dry lead acetate was added, and continued for a further 3 min. The macerate was then filtered through a dry filter paper and a polarimeter reading of part of the filtrate was made using a 400 mm tube. If reducing sugars were to be estimated a portion of the filtrate was deleaded and reducing sugars determined by electrometric titration with a modified Fehling's solution. A check of the polarimetric estimation of sucrose with the chemical estimation by inversion and titration and by taking a polarimeter reading before and after inversion showed that the polarimetric estimation accurately reflected the sucrose content. With the quantities of material and water taken the sucrose per cent cane is equivalent to

$$\frac{\text{Polarimeter reading (in 400 mm tube)}}{0{\cdot}8}$$

The assay of true sucrose per cent cane by the above method was successfully used as the basis of a maturity testing technique and was highly correlated with field results during the favourable ripening weather of the autumn of 1953 and the spring of 1954.

In the autumn of 1954 when heavy rains fell continuously and cane quality was extremely variable, it was deemed necessary to obtain more data about the cane, since the amount of sucrose which it is possible for a factory to extract, is dependent not only on the sucrose content of the cane, but also on the purity (*i.e.* the sucrose expressed as a percentage of the total soluble solids) and the fibre content (*i.e.* percentage of insoluble material). When the purity of the juice is very low a considerable proportion of the sucrose is uncrystallizable and passes into the molasses.

A far more valuable datum than total sucrose per cent cane is the ' available sugar ' per cent cane which takes into consideration the factors militating against recovery of sucrose.

DETERMINATION OF POLARIZATION PER CENT CANE, BRIX AND PURITY BY A STANDARD METHOD.

Five hundred grammes of the brei (or cane ' sawdust ') obtained from sawing 20 canes was accurately weighed and placed in a press and the juice expressed (70 per cent of juice per cent cane was extracted by the press available). The expressed juice and the residue were separately weighed and the per cent polarization and per cent brix in the juice determined. The weight of polarizing material and the brix in this juice was calculated.

Fifty grammes of the residue was digested with 500 cc of boiling water for an hour. After cooling and filtering the per cent polarization was determined and the weight of polarizing material calculated. The brix in the residue was calculated on the assumption that the purity of the juice remaining in the residue is equal to that in the expressed juice. The total brix in the residue was thus calculated. The weight of polarizing material in the expressed juice plus that in the residue gives the weight of polarizing material in the cane, and similarly, the brix in the expressed juice plus that in the residue gives the brix per cent cane: from these the purity of the juice in the whole cane is calculated. Moisture per cent cane was determined by drying a 100 g sample of the fresh brei in a forced draft oven for 4 hr at 100°C.

The per cent fibre in the cane was calculated from the relationship per cent fibre = 100 − (per cent moisture + per cent brix).

The values obtained by the above method were regarded as being sufficiently accurate to serve as a standard for comparison of the blender or macerator method described below.

DETERMINATION OF POLARIZATION PER CENT CANE, BRIX AND PURITY BY THE BLENDER OR MACERATOR METHOD

The procedure adopted was as follows:

(1) One hundred grammes of the brei is used for the determination of moisture per cent cane as in the method described above.

(2) Fifty-two grammes of brei is blended with 460 cc of water for 6 min: no clarifying agent is added.

(A) Filter through cotton or glass wool. Take about 100 cc of the filtrate, add one-third teaspoon of neutral lead acetate and shake in a flask. Filter and determine per cent polarization by polarizing in a 400 mm tube and dividing the reading by 0·8.

(B) Take the remainder of the filtrate, cool to room temperature, and determine the specific gravity in a pycnometer. Convert the specific gravity into brix by using the appropriate conversion table.

The brix per cent cane is calculated as follows:

$$\text{per cent brix in cane} = 460 + \frac{\text{per cent moisture in cane} \times 52}{100} \times \frac{100}{52} \times \text{per cent brix in macerator extract}$$

It is apparent that if the moisture per cent cane, the polarizing solids (sucrose) per cent cane and the total soluble solids per cent cane are known and the fibre content can be derived from the relation per cent fibre = 100 − (per cent moisture + per cent brix), all the important factors required to describe the quality of the cane are available. Moreover, if these data could be ascertained with sufficient accuracy from the maceration of the brei with water, a very rapid method of assay of cane quality would be available.

In the following table the comparative analyses of samples of cane by the blender method and by the standard method are presented.

Type of cane	*Pol in cane* (per cent)		*Brix in cane* (per cent)		*Purity coefficient*		*Available sugar* (per cent)		*Fibre* (per cent)	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
B.47225	14·75	14·42	16·9	16·2	87·3	88·9	13·89	13·70	12·1	12·8
B.41227	12·50	12·10	15·2	14·5	82·2	83·4	11·42	11·14	12·8	13·5
B.46378	12·87	13·22	15·9	16·0	80·9	82·5	11·66	12·10	14·1	14·0
B.4098	12·93	13·12	15·6	15·7	82·9	83·6	11·86	12·10	14·9	14·8
B.40105	12·87	13·43	15·1	16·1	85·2	83·6	11·98	12·37	15·8	14·8
B.37161	14·31	14·65	16·7	17·1	85·7	85·5	13·35	13·65	13·1	12·7
B.34104	13·06	12·97	15·1	15·2	86·5	85·3	12·25	12·07	13·8	13·7
B.40105	15·00	14·43	16·3	16·2	92·0	88·9	14·47	13·71	13·2	13·3
B.37161	12·93	12·21	15·4	14·5	84·0	84·2	11·95	11·29	12·6	13·5
B.40105	12·56	12·97	15·3	15·8	82·1	82·2	11·47	11·84	13·7	13·2
B.40105	12·81	12·79	15·2	15·2	84·3	84·0	11·85	11·82	12·8	13·8
B.4362	14·87	14·91	17·2	17·0	86·4	87·6	13·93	14·06	11·2	12·0
B.37161	14·43	13·79	16·0	16·0	90·1	86·0	13·81	12·89	14·2	14·2
B.37161	12·62	12·50	15·5	15·2	81·4	82·4	11·47	11·44	11·5	11·2
B.37161	13·81	14·18	16·2	16·6	85·2	85·5	12·86	13·21	10·1	9·7
B.37161	13·69	13·82	15·4	16·4	88·9	84·2	13·00	12·78	13·6	12·6
B.4362	12·75	12·80	15·6	15·9	81·7	80·2	11·61	11·54	14·6	14·3
Means of all varieties	13·45	13·43	15·8	15·9	85·1	84·6	12·52	12·45	13·1	13·1

A = Blender method *B* = Standard method

It is apparent that the results by the two methods are in reasonably close agreement and that the macerator or blender method may be used to advantage in maturity testing of cane. Available sugar given in columns 8 and 9 is calculated from the Winter-Carp formula,

$$\text{available sugar} = \text{sugar in cane} \times 1{\cdot}4 \; - \; \frac{40}{\text{purity coefficient}} .$$

Practical application. Maturity testing of cane has been used as a guide for the rational harvesting of cane on all estates under the control of Bookers Sugar Estates during the autumn crop of 1954. In many cases, however, owing to the necessity of harvesting over-age canes of poor quality resulting from the 1953 labour strikes, it has not been possible to take full advantage of the data provided. Nevertheless, it has proved of very great value and will become increasingly so as the legacy of over-age cane, drought affected cane, and leaf-scald infected cane from the strike period of 1953 is disposed of.

In practice, fields or blocks of fields consisting of the same variety, age, *etc*, are sampled at weekly intervals for 3–4 weeks before the crop starts. Sampling continues at 10–14 day intervals until the particular fields are harvested. The management have this data available every week for planning the following week's harvesting programme.

SUMMARY

A rapid method of analyses of sugar cane stalks for assessment of factory quality is described. A suitable sample of stalks are sawn from top to bottom with a circular saw. A sample of the brei is blended or macerated in a high speed blender with water. The percentage of sucrose is determined on a fraction of the extract in the polariscope after clarification and the total soluble materials is determined on another fraction by means of a pycnometer on unclarified extract.

A separate sample of brei is used for moisture determination. From the data so obtained, the sucrose per cent cane, the total dissolved solids, and therefore the purity coefficient, and the fibre per cent cane is calculated. A value for available sugar in the cane which is closely related to recoverable sugar is derived. The method is in current use for maturity testing of sugar cane in British Guiana.

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APPENDIX 1

Specifications of circular saw used

Blade $9\frac{1}{2}$ in. in diameter, with teeth $\frac{1}{4}$ in. pitch, $\frac{1}{8}$ in. deep, offset $\frac{1}{32}$ in. from centre.

Motor: $\frac{1}{2}$ h.p. 1440 r.p.m. Motor geared so that saw ran at twice the motor speed.

Operation

It is preferable to have two operators, one picks a cane up and pushes it against the sawblade. As soon as the separated halves appear behind the blade they are grasped by the second operator who guides the remainder of the cane through, whilst the first operator picks up another cane.

APPENDIX 2

Table 1. Specific Gravity/Brix Conversion Table at 27·5°C

Brix	*Sp. gr.*	*Brix*	*Sp. gr.*	*Brix*	*Sp. gr.*
0·00	1·00000	0·66	256	1·34	521
0·02	008	0·68	264	1·36	528
0·04	016	0·70	272	1·38	536
0·06	023	0·72	280	1·40	1·00544
0·08	031	0·74	288	1·42	552
0·10	039	0·76	295	1·44	560
0·12	047	0·78	303	1·46	567
0·14	055	0·80	1·00311	1·48	575
0·16	062	0·82	319	1·50	583
0·18	070	0·84	327	1·52	591
0·20	1·00078	0·86	334	1·54	599
0·22	086	0·88	342	1·56	606
0·24	093	0·90	350	1·58	614
0·26	101	0·92	358	1·60	1·00622
0·28	109	0·94	366	1·62	630
0·30	116	0·96	373	1·64	638
0·32	124	0·98	381	1·66	645
0·34	132	1·00	1·00389	1·68	653
0·36	140	1·02	397	1·70	661
0·38	147	1·04	404	1·72	669
0·40	1·00155	1·06	412	1·74	677
0·42	163	1·08	420	1·76	684
0·44	171	1·10	427	1·78	692
0·46	178	1·12	435	1·80	1·00700
0·48	186	1·14	443	1·82	708
0·50	194	1·16	451	1·84	716
0·52	202	1·18	458	1·86	723
0·54	210	1·20	1·00466	1·88	731
0·56	217	1·22	474	1·90	739
0·58	225	1·24	482	1·92	747
0·60	1·00233	1·26	489	1·94	755
0·62	1·00241	1·28	497	1·96	762
0·64	249	1·30	505	1·98	770
		1·32	513	2·00	1·00778

Table 2. Correction Factors to Brix Readings for Temperatures Above and Below 27·5°C

Temp in °C	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
				Subtract from readings						
25	0·16	0·15	0·15	0·14	0·14	0·13	0·12	0·12	0·11	0·11
26	0·10	0·09	0·09	0·08	0·07	0·06	0·06	0·05	0·04	0·04
27	0·03	0·02	0·02	0·01	0·01	0·00				
				Add to readings						
27						0·00	0·01	0·02	0·02	0·03
28	0·04	0·05	0·05	0·06	0·07	0·07	0·08	0·09	0·10	0·10
29	0·11	0·12	0·12	0·13	0·14	0·14	0·15	0·16	0·17	0·17
30	0·18	0·19	0·19	0·20	0·21	0·21	0·22	0·23	0·24	0·24
31	0·25	0·26	0·26	0·27	0·28	0·28	0·29	0·30	0·31	0·31
32	0·32	0·33	0·34	0·34	0·35	0·36	0·37	0·38	0·38	0·39
33	0·40	0·41	0·42	0·42	0·43	0·44	0·45	0·46	0·46	0·47
34	0·48	0·49	0·50	0·50	0·51	0·52	0·53	0·54	0·54	0·55

Table 3. Factors for Standardizing the Water Value of the Pycnometer at 27·5°C

°C	*Factor*
25	0·999328
26	0·999589
27	0·999859
28	1·00014
29	1·00043
30	1·00073
31	1·00103
32	1·00136

Example of calculation of brix per cent cane

Weight of water held in pycnometer at 31·5°C = 49·7848 g

,, ,, ,, ,, ,, ,, ,, 27·5°C

(by applying correction from *Table 3*) = 49·8440 g

Weight of macerator extract held in pycnometer at 31·4°C = 50·1328 g

Specific gravity of macerator extract at 31·4°C $= \frac{50{\cdot}1328}{49{\cdot}8440} = 1{\cdot}00579$

According to *Table 1* the specific gravity is equal to 1·49 brix at 31·4°C.

To correct this brix to the normal temperature 27·5°C we add (according to *Table 2*) brix+0·28.

Therefore brix of macerator extract at 27·5°C = 1·77

moisture in cane (as found) = 71 per cent

$$\text{brix in cane} = \left(460 + \frac{71{\cdot}0}{100} \times \frac{52}{1}\right) \times \frac{100}{52} \times \frac{1{\cdot}77}{(100 - 1{\cdot}77)} = 17{\cdot}1 \text{ per cent}$$

APPENDIX 3

METHOD OF FIELD SAMPLING

Two men are detailed to collect the samples: they enter the field or block from north, south, east and west and walk in until quite past the dam beds. They are equipped with a pack of cards numbered from 1 to 20. One operator places a stake in the cane row, the cards are shuffled and one operator draws a card the number of which is not known to the other operator. The latter counts every cane aloud starting from the stake and when he calls the number on the card he is instructed to cut the cane concerned. Alternatively the random numbers are drawn by the supervisor before the men enter the field. In fields planted in long rows along the bed (Woodford Lodge system) randomization of rows on the bed is also made since it has been found that the (better drained) centre rows are frequently of better quality than the side rows.

A Rapid Method for the Determination of Zinc in Sugar Cane Leaf Material

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Introduction

As part of a wider investigation into the micro-element status of sugar cane in British Guiana, a method was required for the rapid approximate assay of zinc.

For the determination of mineral status the tissue selected is the middle portion of the lamina (excluding the midrib) of the leaf showing the highest visible ' dewlap ' or ' joint-triangle ' when the cane plant is $4\frac{1}{2}$–5 months old. Following preliminary trials with the official dithizone method and with the di-beta-naphthyl-thiocarbazone method described in Snell and Snell (1949) both of which are relatively long and tedious, a simpler dithizone method has been evolved which has proved both rapid and sufficiently accurate for the purpose required.

The technique was suggested by the method described by Lakin, Stevens and Almond (1949) for the field determination of zinc in soils, suitably modified for plant material and using a spectrophotometer for the ultimate evaluation of zinc. It has been checked against zinc assays by the *Aspergillus niger* technique of Nicholas and Fielding (1950).

Basic Features of the Method

Dried and finely ground leaf material is digested with concentrated sulphuric acid aided by hydrogen peroxide. The digest is neutralized with a strong solution of potassium hydroxide to the neutral point of bromocresol green and buffered by addition of acetate buffer to a pH of four to five. Addition of sodium thiosulphate largely prevents the reaction of other metals. The chief interfering element—copper—is only present to the extent of 5 to 10 p.p.m. in sugar cane leaf material under British Guiana conditions, and interference by calcium, iron, aluminium and phosphate appears to be very small and does not differ appreciably between samples. The zinc combines with dithizone to form the reddish keto complex which results in a gradual gradation from green (unreacted dithizone) through blue, purple-violet, to red violet with increasing quantities of zinc. Using a blank containing reagents but no zinc as the reference standard in the spectrophotometer, the transmission of the carbon tetrachloride extract is determined at a wave length of 535 mμ.

Reagents Required

Concentrated sulphuric acid A.R. grade.

Glass distilled water.

Acetate buffer. Mix 5 vol. of 2N sodium acetate with 2 vol. of 2N acetic acid and shake repeatedly in a separatory funnel with 0·01 per cent

solution of dithizone in carbon tetrachloride, discarding the carbon tetrachloride layer each time. Continue this operation until the dithizone retains its original colour.

Sodium thiosulphate	50 g of A.R. grade $Na_2S_2O_3.5H_2O$ in 100 ml of glass distilled water.
Standard zinc solution	containing 10 μg of zinc per millilitre.
Carbon tetrachloride	Redistilled.
Dithizone	0·0025 per cent (weight by volume) in redistilled carbon tetrachloride.
Potassium hydroxide	100 per cent KOH in water.
Bromocresol green	0·025 per cent.

Apparatus

2 doz. Pyrex digestion tubes, 9½ in. × 1 in.
2 doz. Pyrex test tubes, 5 in. × ½ in. with ground glass stoppers.
2 doz. 1 cm diameter spectrophotometer tubes.
Pipettes, 1 ml, 2 ml and 5 ml.
One small porcelain boat.
One steel wire about 10 in. long, hooked at the end.
Any suitable make of spectrophotometer. In the present work a Unicam D.G. spectrophotometer was used.

PREPARATION OF A STANDARD CURVE FOR ZINC

Into Pyrex digestion tubes, well washed with hot acid and rinsed with glass distilled water, place zero, 1 ml, 2 ml, 3 ml, 4 ml, 5 ml, 6 ml and 8 ml of the standard zinc solution. Heat the tubes gently until the zinc solution has evaporated to dryness and add to each tube 2 ml of concentrated H_2SO_4 A.R. grade. Heat for about 20 min. Let the tubes cool and add carefully, drop by drop with frequent mixing, 100 per cent KOH solution. Before the neutralization of the sulphuric acid is complete deposition of potassium sulphate occurs. At this stage add three drops of 0·025 per cent bromocresol green and continue the addition of the KOH solution drop by drop, mixing constantly.

Neutralization is effected when the last drop of KOH changes the bromocresol green from yellow to blue. Ultimately one small drop of KOH will effect the change: there must be no excess of KOH over this amount. To the neutralized solution add exactly 7 ml of the acetate buffer and 1 ml of the sodium thiosulphate solution. Mix well and bring to the boil, let simmer for 2 min. Allow to cool.

Clean by washing with hot dilute HCl a sufficient number of the Pyrex test tubes fitted with ground glass stoppers. Rinse the test tubes with glass distilled water. Into each of these tubes pipette 5 ml of the dithizone solution. Pipette 2 ml of the supernatant liquid from the blank and zinc standards and add to the dithizone in the Pyrex test tubes: stopper the tubes and shake vigorously for 1 min. Let the carbon tetrachloride and aqueous phases separate completely (3 min). By means of a 5 ml pipette, which is closed with the finger when passing through the aqueous layer, remove about 4·5 ml of the carbon tetrachloride layer and place in the acid washed, thoroughly cleaned absorptio-meter tubes (1 cm diameter). Using a wave-

length of 530 mμ, zero the spectrophotometer against the blank to which no zinc was added. This solution should be almost as green as the pure dithizone solution or only very slightly bluish green. Measure the transmittance of the other standards which were made up with 10, 20, 30, 40 . . . μg of zinc, and plot the curve of transmittance against the known zinc content.

PROCEDURE FOR SUGAR CANE LEAF MATERIAL

The dried and finely ground lamina of the leaves showing highest visible dewlap is intimately mixed and a sample of 0·25 g weighed in a small porcelain boat and transferred into Pyrex digestion tubes using a steel wire hook so that the dry matter is deposited at the bottom of the tube. Add 2 ml of concentrated H_2SO_4 and heat to digest the dry matter, cooling and adding a few drops of hydrogen peroxide A.R. grade at intervals to aid the digestion.

The solution is generally colourless and completely digested after about 20 min. With the plant material assays include one blank to which the reagents only are added and one standard. One millilitre of the standard zinc solution (containing 10 μg of zinc) is used as the standard and is evaporated to dryness before adding the 2 ml of conc. H_2SO_4.

When the digests have cooled, neutralize carefully drop by drop to the bromocresol green end point with 100 per cent KOH as described for the zinc standards in preparing the standard curve, add 7 ml of the acetate buffer, 1 ml of the thiosulphate solution; heat to boiling and let simmer for 1 min, then allow to cool. Pipette 2 cc of the supernatant liquid from each of the blank, the zinc standard and the digested plant material samples to 5 cc of the dithizone solution in clean Pyrex tubes. Shake vigorously for 1 min, let the phases separate and transfer about 4·5 ml of the carbon tetrachloride layer to 1 cm absorptiometer tubes and, using the blank to zero the instrument, determine the transmittance at 535 mμ. The standard is used as a check against any possible contamination and should give the same or very nearly the same transmittance as the equivalent amount on the prepared standard zinc transmittance curve.

In preparing the standard zinc curve the transmittance values are plotted against the total amount of zinc introduced into the digestion tubes (10, 20, 30, 40 . . . μg) since the same aliquot (2 ml) is taken for addition to the dithizone in each case. Using the same aliquot (2 ml) from the digested plant material, the calculation of zinc content is thereby simplified. For example, if the plant sample gives the same reading as 20 μg of zinc, this amount of zinc is contained in 0·25 g dry matter and the zinc content is therefore 80 p.p.m.

COMPARISON OF ZINC DETERMINATIONS MADE WITH THE RAPID DITHIZONE METHOD AND ASSAYS WITH *ASPERGILLUS NIGER* (MULDER STRAIN)

Through the courtesy of Professor Wallace of Long Ashton Research Station a slant of *Aspergillus niger* (strain M) was obtained and has been successfully used for the determination of copper and zinc in sugar cane leaf material. The nutrient solution used was solution C (Nicholas and Fielding, 1950) with the exception that dextrose was replaced by sucrose.

The nutrient solution was freed of zinc by repeated extraction with dithizone in carbon tetrachloride at pH 6·0. A standard curve for zinc was obtained by plotting the weight of washed and dried fungus against known quantities of zinc added to the zinc-free basal medium. At the same time 0·1 g of the dried and ground leaf samples were added to the zinc-free basal medium. All the petri dishes contained 50 ml of nutrient solution and were cultured for five days. In the case of the plant samples it was found easy to separate the residual plant material from the mycelium by floating the mycelium with water and decanting off the residual dry matter from below.

The mycelium was filtered through washed, dried and tared filter paper, followed by thorough washing and drying for 24 hr at 90°C.

The curve of dry weight of fungus against added zinc is shown in *Figure 1*. The zinc content of samples of sugar cane leaf material determined by the two methods gave *Table 1*.

Table 1

Location and nature of sample	*Zinc in dry matter* (p.p.m.) *Aspergillus method*	*Rapid dithizone method*
NCO 310 grown in tubs in medium containing 1/3 rotted bagasse, 1/3 frontland clay and 1/3 rotted filter cake ..	120	136
NPK Factorial Trial		
Rose Hall Estate		
Treatment $N_1P_1K_1$ +Lime	60	51
,, $N_1P_0K_0$+Lime	59	58
,, $N_1P_0K_0$—Lime	47	58
Port Mourant Estate		
Treatment $N_1P_1K_1$ +Lime	55	42
,, $N_1P_0K_0$+Lime	45	53
,, $N_1P_0K_0$—Lime	50	43
L.B.I. Estate		
Treatment $N_1P_1K_1$ +Lime	35	51
,, $N_1P_0K_0$+Lime	54	54
,, $N_1P_0K_0$—Lime	45	54
Mean of all determinations	57	60

The agreement between the two methods is considered to be sufficiently good to show that there is no major interference in the proposed rapid method and that the element estimated is actually zinc. The *Aspergillus* method is itself not very precise as small errors in weighing can result in larger errors in the assay of the metal. The method has, therefore, been adopted for the determination of the zinc status of sugar cane in British Guiana.

Very little comparative data is available for sugar cane grown in other territories: values of 70–100 p.p.m. in the dry matter of leaf sheaths have been reported from Hawaii. Work on the determination of critical values of zinc in the selected leaf samples is in progress, in order to establish sufficiency limits for optimum growth for this metal. It is interesting to note that in soil samples from Plantation Blairmont sent for spectroscopic analysis to the U.S.A. by G.L.C. Bourne in 1949 Zinc was reported as

'looked for, but not found'. On the other hand, PAUL (1953) reported values of 32 p.p.m. and 42 p.p.m. of zinc soluble in N/2 acetic acid for exhausted and virgin pegasse soils respectively.

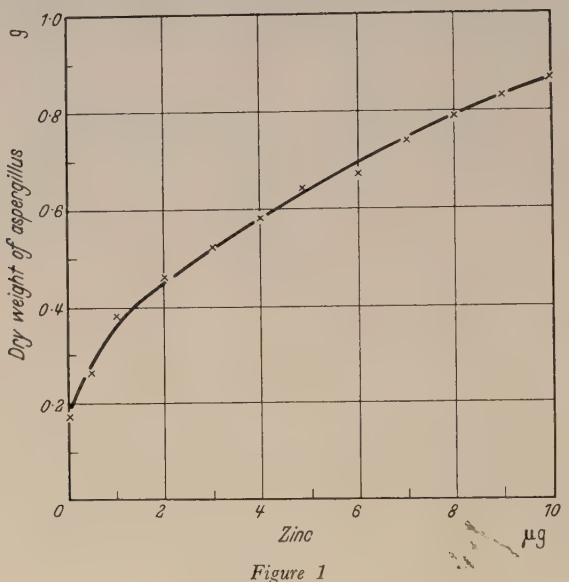

Figure 1

SUMMARY

A rapid and sufficiently accurate method for the determination of zinc in sugar cane leaf material is described. The method is an adaptation of a technique described by LAKIN, STEVENS and ALMOND (1949) for the field determination of zinc in soils. Results obtained by the proposed method are in substantial agreement with assays made by the *Aspergillus niger* (M) technique of NICHOLAS and FIELDING (1950).

(*Received October 1954*)

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Thinning of Grapes with Naphthalene Acetic Acid

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INTRODUCTION

Thinning of table grapes by removal of some flowers at the full blossoming stage is a matter of common practice but is costly. Experiments were therefore made in thinning Faumy grapes with naphthalene acetic acid, to decrease the expenses of thinning. The Faumy variety is widely spread in Egypt.

REVIEW OF LITERATURE

Palieri in 1936, at Maccarese near Rome, tried the effect of spraying the bunches three or four times during the flowering period with a proprietary chemical solution (formula not given) in the hope that the flowers which were opened would become abortive and fall off, and that the unopened flowers would not be affected. With this chemical, not only was thinning uniformly distributed, but it also proved to be much cheaper than thinning by hand. The following advantages were claimed: greater uniformity of grapes in the bunch; increased length of the main stem of the bunch; slightly earlier ripening; increased size of individual grapes and hence of bunches.

Pentzer (1941) indicated that naphthalene acetic acid, when applied in a pre-harvest spray or as a dip to freshly picked grapes, failed to increase berry adherence significantly in any of the varieties tested, which included four *vinifera* varieties and one each of *babrusca* and *rotundifolia*.

Carlone in 1951 stated that β-naphthoxyacetic acid applied at various concentrations at different stages of flowering increased the flower drop in varieties Barbara and Horslevelu.

Weaver and Williams (1951) reported that when Blanch Corinth vines were sprayed at full blossoming with 4-chlorophenoxy-acetic acid at 25 p.p.m., many large clusters developed.

MATERIALS AND METHODS

Experiments were conducted in 1950 and in 1951 on the University farm. Three vines of the Faumy variety were used. Clusters of each vine were classified into three groups. The first and second groups were sprayed at the full blossoming stage with naphthalene acetic acid at concentrations of 0·05 per cent and 0·005 per cent, respectively. The third group was left as a control.

Before spraying each group, the clusters of the other two groups were enclosed in paper bags to prevent direct contact with the spray. These bags were removed when the sprayed clusters had dried.

RESULTS AND CONCLUSIONS

Spraying with naphthalene acetic acid at 0·005 per cent was not effective in thinning the Faumy grape variety at the full blossoming stage. At this concentration there was no difference between the sprayed and unsprayed bunches on the same vine in average weight of the bunch, average number of berries, or their average weight.

The effective concentration was 0·05 per cent. This increased the flower drop and decreased the number of berries. In 1950 the average number of berries on sprayed bunches on vines 1, 2, and 3 was 90, 90, and 91 respectively, while the averages for unsprayed bunches on the same three vines were 106, 109, and 106 respectively.

In 1951 the average number of berries on the sprayed bunches of the three vines were 94, 86, and 90, while the averages for unsprayed bunches were 104, 105, and 106.

Table 1. Effects of Thinning of Faumy Grapes with Naphthalene Acetic Acid on the Weight and Number of Berries—1950-1951

Vine No.	*Treatment*	*Year*	*Weight and number of berries*		
			Weight per 5 bunches (kg)	*Average number of berries in bunch*	*Weight per 100 berries* (g)
	Spraying with 0·05% acid	1950	2·200	90	430
		1951	2·100	94	450
		Aver.	2·150	92	440
1	Spraying with 0·005% acid	1950	2·200	109	385
		1951	2·000	105	375
		Aver.	2·100	107	380
	Unsprayed bunches	1950	2·100	106	385
		1951	2·000	104	385
		Aver.	2·050	105	385
	Spraying with 0·05% acid	1950	2·300	90	460
		1951	2·100	86	440
		Aver.	2·200	88	450
2	Spraying with 0·005% acid	1950	2·100	107	385
		1951	2·100	105	385
		Aver.	2·100	106	385
	Unsprayed bunches	1950	2·300	109	390
		1951	2·100	105	390
		Aver.	2·200	107	390
	Spraying with 0·05% acid	1950	2·000	92	445
		1951	2·200	90	435
		Aver.	2·100	91	440
3	Spraying with 0·005% acid	1950	2·200	110	390
		1951	2·200	106	380
		Aver.	2·200	108	385
	Unsprayed bunches	1950	2·100	106	380
		1951	2·200	106	380
		Aver.	2·150	106	380

These figures indicate that the average number of berries was decreased in the sprayed bunches in each year and for each vine. The percentage of this decrease was 15·2 per cent in 1950 and 15·0 per cent in 1951.

This decrease in the number of berries was accompanied by an increase in their weight. In 1950 the average weights of 100 unsprayed berries on vines 1, 2, and 3 were 385, 390, and 380 g respectively, while the average weights of 100 sprayed berries on the same three vines were 430, 460 and 435 g. In 1951 the corresponding figures were 385, 390, and 380 g for unsprayed berries, and 450, 440, and 450 g for sprayed berries.

Thus the average weight of 100 berries was increased on each vine and in each year as a result of spraying with naphthalene acetic acid at 0·05 per cent. The percentage increase was 14·0 per cent in 1950 and 15·6 per cent in 1951.

From the data shown in *Table 1*, this increase in the average weight of the sprayed berries was not accompanied by an increase in the average weight of the sprayed bunch. There was no difference between the average weight of the sprayed and unsprayed bunch, on each vine and in each year.

SUMMARY

Spraying with naphthalene acetic acid at 0·05 per cent at full blossoming time was effective in thinning berries of the Faumy grape variety. This thinning increased the average weight of berries without any appreciable increase or decrease in the average weight of bunches following spraying.

(*Received February 1955*)

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Tobacco Anthracnose II: Some Physiological Characteristics of the Causal Organism in Relation to Epidemiology

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In a previous communication[2], brief mention was made of some of the environmental factors affecting the occurrence and intensity of anthracnose (*Colletotrichum tabacum* Böning) and of the soil-borne nature of initial infections on tobacco seedlings. The present paper reports the results of experiments to determine the physiological characters of the fungus and their possible bearing on the control of the disease.

BEHAVIOUR OF THE FUNGUS UNDER CONTROLLED ENVIRONMENT

Methods

Except as otherwise indicated, cultural observations were made on Difco cornmeal agar. The pH series was adjusted to the various H-ion concentrations by addition of N/10 HCl or N/10 NaOH. Plates for the temperature series were placed in the incubator at room temperature, or in the refrigerator. Humidity observations were made in sealed jars over various saturated salt solutions as listed by McLean and Cook[1]. Spore counts were made with a Thoma haemocytometer and represent the mean of nine readings. Inoculum for inclusion in soil was grown on a mixture of cornmeal, sand and water in the proportion of 1:1:1·5.

pH Relations

The striking feature of the effect of pH was that the fungus favoured a neutral to alkaline medium, the optimum pH for growth being seven while vigorous growth was maintained at as high pH as nine. Acid conditions caused a steep fall in the growth rate. Sporulation was approximately inversely correlated with the linear growth rate: maximum sporulation occurred at pH 9.

It has been mentioned previously[2] that anthracnose is frequently found to break out initially on patches of soil of high pH. The reason for this has not been determined, but it is suggested that a high pH favours growth and/or sporulation of the fungus in the soil itself apart from having undesirable effects on the host. If this should prove to be the case, liberal applications of green vegetable matter, flowers of sulphur or sulphate of ammonia to infected soils would assist control by lowering the pH.

Temperature

C. tabacum grew vigorously over quite a narrow range of temperature, 20–30°C. The growth rate fell off steeply above and below this restricted

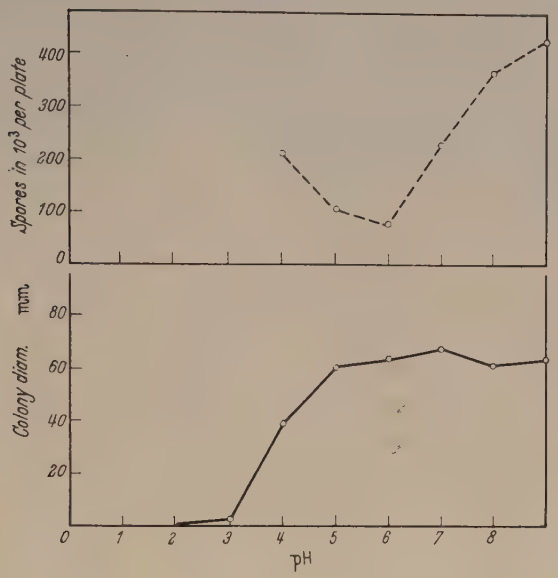

Figure 1. Effect of initial pH of culture medium on growth and sporulation of C. tabacum *at 25°C*

range. Under normal seasonal conditions in Northern Rhodesia, temperatures are ideally suited to the fungus. During October, temperatures fluctuate between 80–100°F (26–37°C) and in November between 70–80°F (20–26°C). It is during these months with the beginning of the rains that anthracnose makes its first appearance in the tobacco beds.

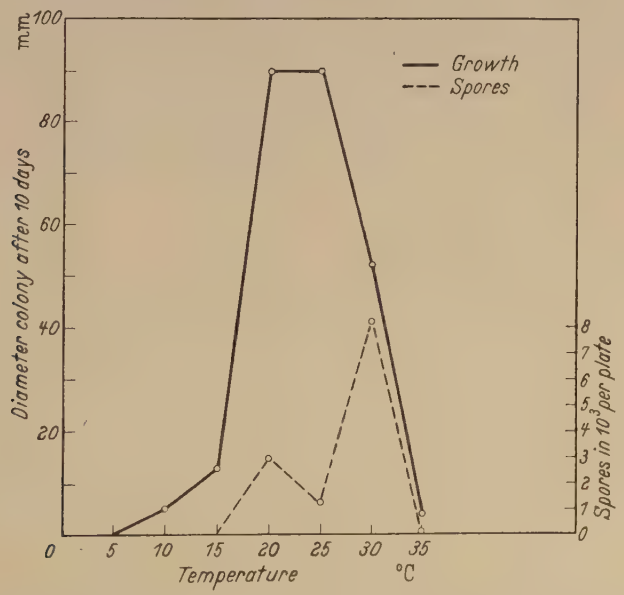

Figure 2. Effect of temperature on linear growth and sporulation of C. tabacum

Humidity

Anthracnose lesions cut from infected leaves were used for the humidity observations, being placed on slides in closed jars as described. After seven days, pieces of leaf tissue of similar size were placed in 10 cc water to which a little Lissapol detergent was added to assist spore removal. Haemocytometer readings are given in *Table 1.*

Table 1. Effect of Relative Humidity on Sporulation of C. tabacum *on the host*

R.H.	*Spores/10* cc
100	4430
98	3160
95	1030
93	400
90	200
88	160
86	30
84	0

Sporulation was extremely sensitive to the relative humidity of the atmosphere. Theoretically, ventilation and sparing use of water on the tobacco beds to reduce relative humidity below 86 should check the spread of anthracnose by inhibiting the sporulation of the fungus on existing lesions. Relative humidity during October is approximately 50–60 but excessive watering and the advent of local thunderstorms will cause a sharp rise thereby bringing about conditions suitable for the development and spread of the disease.

The germination of *C. tabacum* spores at various humidities was also determined. Streaks of concentrated spore suspension were made on collodion films on microscope slides and placed in sealed jars over salt solutions. Slides were examined after 16, 40, and 64 hr. Results are shown in *Table 2.*

Table 2. Effect of R.H. on Spore Germination of C. tabacum

R.H.	*Germination (per cent)*		
	16 hr	40 hr	64 hr
100	2·3	83·9	94·5
98	0	71·1	86·0
95	0	4·9	10·0
93	0	0	0

Spore germination followed the same trend as sporulation but was even more sensitive to relative humidity. This explains the pin-point spotting (' secondary ') phase of anthracnose[2] late in the season when atmospheric humidity is high enough to permit of profuse sporulation followed by a high percentage of spore germination. The advent of dry periods results in a sudden check to the appearance of ' secondary ' lesions. Humidity is undoubtedly the most important factor governing the appearance and spread of the disease.

SOME OBSERVATIONS ON PATHOGEN/SUSCEPT RELATIONS

Susceptibility of Newly-germinated Tobacco Seedlings

It has frequently been observed that when seed is sown in inoculated soil, or in infected seed beds, there is little or no pre-emergence loss and that several days elapse after emergence before the young seedlings become infected with *C. tabacum*. The possibility that the seedlings might pass through a period of relative non-susceptibility following germination was investigated since this has an important bearing on the timing of the application of the fungicidal sprays used for control.

Experiments carried out with seedlings germinated on filter paper in petri dishes and inoculated with spore suspension, showed that seedlings were susceptible immediately after germination and that the apparent non-susceptibility of newly-germinated seedlings must be due to other causes (*Table 3*).

Table 3. Time Taken for Appearance of Lesions after Inoculation with C. tabacum *spores* (room temp.)

Date of Inoculation	*Date of appearance of lesions*	*Time* (days)
30.9.54 (just germ.)	4.10.54	3
4.10.54	6.10.54	2
6.10.54	8.10.54	2
9.10.54	13.10.54	3

Two reasons are advanced for the delay in the appearance of infections in infected soil: (*a*) spore inocula are more effective than mycelial and (*b*) leaves are more susceptible than stems. Tests were made with spore and mycelial (culture) inocula using seedlings germinated on filter paper in petri dishes. Inoculum was placed either on the two young leaves or in contact with the stems. Results are given in *Table 4*.

Table 4. Effect of Inoculation of Leaves and Stems with Spore and Mycelial Inocula

	Seedlings with lesions after 6 days (per cent)	
	Leaves	*Stems*
Spore suspension	66	8
Mycelium (culture)	6	2

When seedlings germinate the leaves are initially clear of the soil by as much as $\frac{1}{4}$ in., particularly when the beds have been covered. Apart from splash on the undersides, the only avenue of infection from the soil is via the stems. As stems are so much less susceptible than leaves, at least part of the delay in the appearance of infections can be accounted for. Furthermore, on the assumption that inoculum from the soil is mycelial, a further portion of the delay may be resolved. It is usually not until the young leaves actually lie in contact with the soil that ' primary ' lesions appear. The appearance of ' secondary ' infection as a result of sporulation on the

' primary ' lesions is extremely rapid, often occurring within 24 hr after the first ' primary ' lesions have been noticed. This rapid appearance of secondary pin-point spotting following sporulation is evidence in itself for the effectiveness of spore inocula.

Biological antagonism to C. tabacum

Both the Tobacco Advisory Staff and farmers have expressed the opinion that nursery beds burned over the surface with brushwood, primarily for weed control, seem to develop anthracnose more readily than those not so treated. This observation may stem from two main causes: (*a*) burning may destroy soil micro-organisms that are antagonistic to *C. tabacum*, and (*b*) the ash left on the surface of the beds after burning may so alter the soil pH as to favour the fungus (see *Figure 1*). Inoculum not destroyed by the burning or brought in subsequently would be given an ideal environment in which to develop.

An experiment was carried out to determine the effect of soil sterilization on subsequent disease development. Samples of soil were sterilized by autoclaving, later inoculated with *C. tabacum* and sown with tobacco seed. A further set of soils was inoculated and sown but not sterilized. The percentage survival of seedlings after four weeks was 6·6 and 11·1 in the two sets respectively. Thus there was a definite indication of biological antagonism to *C. tabacum* in fresh soil.

In another experiment, trays of soil were inoculated with *C. tabacum*, some being sown with Italian Rye Grass, others left bare. After three weeks, the Rye Grass was turned into the soil to promote intense biological activity and tobacco seed was sown in the trays. Percentage survival of seedlings after four weeks was 47·5 in the Rye Grass trays and 38·0 in the trays left bare. There was, therefore, a further indication of biological antagonism to *C. tabacum* in the soil.

GENERAL DISCUSSION

Of the several factors discussed in relation to the epidemiology of tobacco anthracnose, a number of these are capable of alteration so as to assist control of the disease.

It is now generally recommended that other means of weed control be used in preference to burning, *e.g.* hormone weed killers or hand pulling after weeds have been encouraged by heavy waterings before the beds are required. The discontinuance of burning will assist in maintaining the soil pH within satisfactory limits and will ensure that the soil micro-flora is not destroyed.

Temperature is not susceptible of control, but sites on slopes that are well ventilated are generally cooler than those in protected localities and should be chosen in preference for nurseries. Adequate air circulation also helps to maintain a lower relative humidity. Apart from the choice of well ventilated nursery sites, sowings of seed should be made as lightly as is compatible with a good stand of seedlings. A rough guide to the quantity of seed required for 30 square yards of bed is 1/6 oz., but this varies according to local conditions.

The data presented on the period of apparent non-susceptibility strongly suggest that infections may actually occur from the soil some time before lesions become apparent. Once ' primary ' infections are established, the ' secondary ' phase of the disease sets in very rapidly and at this stage is virtually beyond control. Work has therefore been directed latterly towards (*a*) soil disinfection to eliminate soil-borne inoculum and thus check the development of ' primary ' lesions, and (*b*) towards protective spraying to forestall the ' secondary ' phase of the disease. As the seedlings are susceptible from the time of germination, the earlier that protective sprays can be applied, the better. It has hitherto been the practice to commence spraying when the seedlings attain the size of a shilling, *i.e.* 2–3 weeks after germination. This may prove too late to check the appearance of anthracnose. Trials with Bordeaux mixture and several of the new organic fungicides have shown that half strength mixtures can be used with safety within 1–2 weeks of germination, *i.e.* not later than three weeks after sowing the seed. Change-over to the full strength mixtures is made at the ' shilling ' size. This practice is now generally recommended.

SUMMARY

(1) pH, temperature and humidity relationships of *C. tabacum* are presented.

(2) Seedlings are susceptible immediately after germination and do not pass through a period of non-susceptibility although this may appear to be the case. Leaves are more susceptible than stems and spore inocula more effective than mycelial.

(3) There are indications that components of the soil microflora are antagonistic to *C. tabacum*.

(4) Control measures are discussed with reference to the foregoing factors.

ACKNOWLEDGEMENT

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[1] McLean, R. C. and Cook, W. R. I. (1952). *Plant Science Formulae*, London, 1952

[2] Riley, E. A. (1954). ' Anthracnose: A Serious Disease of Tobacco Nurseries in Northern Rhodesia caused by *Colletotrichum tabacum* Böning ', *Trop. Agriculture Trin.*, **31**, 307–311

Book Reviews

WORKING PARTY'S REPORT ON THE MECHANICAL CROP PRODUCTION SCHEME

Sudan Government Ministry of Agriculture, September 1954. 48 *pp.* 22 appended maps, diagrams and tables

One of the objects of producing this report was to assemble information on which the future policy of mechanized agriculture in the Sudan could be based. It contains a great deal of general interest and the Sudan Government's decision to have it printed will be much appreciated by those who are faced with similar problems in other parts of the world. The report deals mainly with large-scale production of sorghum and safflower, and mentions the possibility of introducing groundnuts, cotton and sesame. —J.E.M.

LAND TENURE IN BASUTOLAND

V. Sheddick. Colonial Research Studies No. 13. H.M. Stationery Office, 1954. 196 *pp.* 25*s*

Several studies of land tenure in colonial regions by anthropologists and sociologists have recently been published; this book is one of those which will be of most use to agricultural administrators in the area concerned. Besides delving properly into the historical origins and customary nature of Basuto tenure, it deals with such practical modern problems as the rights held in land by soldiers who are away on active service. A clear picture is given of the pattern of settlement in scattered homesteads, hamlets, or more rarely, villages—a very important aspect of rural life which too many descriptive writers simply leave undescribed. There is a section on agricultural practice and another on animal husbandry and land tenure. A number of excellent photographs, including some taken from the air, help to make clear the different environments which are described.

In a foreword from the Commonwealth Relations Office, it is stated that the Basutoland Administration does not accept all Dr. Sheddick's conclusions. For example, exception is taken to his statement that grazing restrictions were imposed on the Basuto, though it is admitted that measures to that end were introduced. In spite of such comparative *minutiae*, the Administration are able to express themselves as grateful to Dr. Sheddick for a valuable study; and readers concerned with the region will agree. —G.B.M.

UGANDA PROTECTORATE: REPORT OF THE AGRICULTURAL PRODUCTIVITY COMMITTEE

Govt. Printer, Entebbe, 1954. 148 *pp.* Sh. 5/50

This report is published as a supplement to the Report of the Development Council entitled 'A Five-Year Capital Development Plan 1955–1960'. A

foreword states that the recommendations of the Committee have been accepted in full by the Government subject to endorsement by the Legislative Council.

On the whole the policy recommended is conservative; the same treatment as before, only more of it. In some territories this would smack of complacency; in Uganda, where soils and climate are already favourable to agriculture, and the foundations of agricultural progress have been reasonably well laid, it is probably sound. Individual peasant agriculture is accepted as being the continuing mainstay, though the emergence of a class of 'farmers' from among the 'cultivators' is envisaged, and co-operative group farms are mentioned. The chief innovation is the suggestion that partnerships should be formed between Native Governments and commercial enterprises to develop particular areas, and between African landowners and commercial concerns who can provide them with capital and skill. It is thought that the Uganda Development Corporation Ltd. can play a part on these lines, and the formation by it of an Agricultural Development Company is suggested.

But if the operations proposed are not very revolutionary, their scale is to be much stepped up. The Committee proposes capital expenditure of £1,985,900 and recurrent expenditure of £1,085,350 over the five years 1955–60. The largest slices of expenditure go to mechanical cultivation, farm institutes, developments in Kigezi and Karamoja districts, and grain storage. It may be optimistic to suppose that 66 additional expatriate staff with agricultural, veterinary, and forestry qualifications can be obtained over the period. Some will say that the whole plan is optimistic when it is admitted on p. 88 that the mechanized project known as Busoga Farms has got through some £90,000 in the last few years with very little to show for it.

Readers of the report will be grateful for one map showing the main ecological zones of the country and another which shows the rainfall probability with 9:1 confidence limits. On p. 51 it comes as rather a shock to read that in a region where 'early burning' of grassland has so long been preached to the people, it is now considered that *late* burns only are permissible.—G.B.M.

MANUEL DU PLANTEUR D'HEVEA

Tome 1. Culture—exploitation

J. G. Bouychou. Institut Francais du Caoutchouc, 42, Rue Sheffee, Paris (16e), 1954. 151 *pp.* (illus.) mimeographed. 1,000 *fr.*

This publication is a useful and essentially practical treatise covering all aspects of cultivation of Para rubber from the initial preparation of the land to the production of latex in the field. The author writes from many years' experience in Indo-China drawing where necessary on recent work in Malaya and Java. The early chapters of the book will give the practical planter the essentials of the botany and physiology of *Hevea*, an understanding of which is fundamental to successful cultivation and production. Later chapters deal with the propagation and production of clonal material,

cultivation practices and tapping systems, diseases and pests of rubber, and their control, while the final chapter describes some of the other rubber-producing plants of commerce.

Throughout the whole of the book the practical aspect is very much to the fore and the illustrations and diagrams well supplement the text. A reprint in English of this publication should be of real value to rubber planters everywhere.—A.B.K.

SILAGE FERMENTATION

A. J. G. Barnett. Butterworths Scientific Publications, London, 1954. 208 *pp.*, 52 illus. 27*s* 6*d*

A. J. G. Barnett and his co-workers have made several contributions to the knowledge of the biochemistry of silage fermentation, and it is therefore fitting that this worker should write a review covering most of the work undertaken to date in this field. The book has been designed more for the student of science than the field practitioner, but there are some parts which could be profitably read by those unaccustomed to scientific terminology.

The reviewer finds the section dealing with laboratory silos of great value, since it probably represents the first time this subject has been reviewed. A feature which makes the book all the more readable is the frequent touching by the author upon subjects related to, but not necessarily part of the main theme of the text. For example, on page 21 the author, in discussing the addition of urea to silage, diverges for a moment to the subject of the ammoniation of crop residues. Another example is found on page 67 in a discussion about vitamins and vitamin losses in silage, when Barnett rekindles the interest by momentarily discussing the possible importance of the presence of vitamin K upon the killing effect in plants by weed-killers of the 2, 4-D type.

In the earlier part of this well-written text Barnett discusses silage-making in the field and laboratory, dealing also with the various nutritive losses suffered in the preservation of hay and silage. Chapters five and six deal with the chemistry of silage fermentation, whilst chapters seven and eight discuss methods employed in silage analysis, including several of the more modern techniques such as the use of paper and gas-phase column chromatography.

The final chapter concerns the digestibility and biological value of silage. Barnett has discussed many of the difficulties involved in the determination of the digestibility of forages in general, and silage in particular, under temperate conditions. In tropical regions further difficulties arise. Whether some of the relationships determined for silage made from temperate grasses will hold for tropical fodders remains to be seen.

This book should be most useful to those concerned with the preservation of tropical forages, since it provides an excellent review of both fundamental and applied work carried out with silage-making in temperate areas.—J.R.H.

OBITUARY

Professor R. E. D. Baker

With great regret we have to record the death of Professor Baker, which occurred on 19 November 1954.

Richard Eric Defoe Baker was born in 1908 and educated at Oundle and Cambridge where he read Botany and obtained a first class in Part II of the Natural Sciences Tripos. He came to the Imperial College of Tropical Agriculture as a postgraduate student in 1932, and in the following year was awarded the Associateship and appointed to the staff as Lecturer in Mycology. So well did he fill the post that when Professor H. R. Briton-Jones died in 1936 Baker was put in charge of the Department of Mycology and Plant Pathology. In 1945 he was promoted to the Chair.

As a plant pathologist he worked on several important diseases of tropical crops and many minor ones. Some of his earliest research was on gummosis and scab of citrus; later he turned to an intensive study of the witches' broom disease of cacao and published on that subject a long series of papers in *Tropical Agriculture*, full of careful observations and reflecting a soundly practical attitude towards control measures.

At the same time he kept up wider botanical interests and when the Chair of Botany became vacant in 1949 Baker was so evidently suited to fill it that the two Departments were amalgamated and he became Professor of Botany and Plant Pathology. The change brought him responsibility for the botanical sections of the banana and cacao research schemes at the College including oversight of the field programme at River Estate. In 1948 he visited East Africa in connection with the banana-breeding programme, and in 1952 led an expedition to Colombia to collect material for cacao research.

Plant hunting was very much to Baker's liking. He built up an excellent herbarium of Trinidad fungi, and was equally keenly interested in the flowering plants of the Colony. One of his favourite relaxations was a botanizing tramp in forest or savannah, collecting material and records for the *Flora of Trinidad and Tobago*, which he edited from 1947.

He also found time for less academic pursuits. Old students of one period will remember him as a useful member of rugger and hockey teams. He served for several years as Hon. Secretary of the Amalgamated Clubs. In fact there were few, if any, College activities in which ' Dick ' took no part; and if there was work to be done he usually did more than his share. During the war he gave generously of his time and energy to the Trinidad Volunteers and later to the Special Constabulary.

The loss of Baker's abilities and experience is a blow to the whole of agricultural science in the tropics, falling the harder on the College that he served so loyally and well by destroying the bright promise of still greater services to come. The loss of his attractive personality is grievous to his colleagues and his many friends.

He married in 1935. To Mrs. Baker and their four daughters we respectfully extend our deep sympathy.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

A Report on Cacao Research, 1953. 10*s* 6*d*

Reprints are available, at varying prices, of articles in the Cacao Research Reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao (1945–1951 Report)—Price 5*s* plus postage.

Memoirs—Economic Series No. 2: Peasant Farming: Report on Peasant Experimental Farms at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., by A. L. JOLLY. 1*s*

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

Volume I Ranunculaceae to Araliaceae complete in eight parts and index. 26*s* 6*d*

Volume II Part 1. Rubiales. 2*s*
Part 2. Asterales to Primulales. 3*s* 6*d*
Part 3. Ebenales to Polemoniales (in part). 5*s*
Part 4. Polemoniales (in part). 5*s*
Part 5. Scrophulariaceae to Acanthaceae. 5*s*
Part 6. Verbenaceae and Labiatae, in the press.
Further parts are in preparation.

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

Editorial

International Committee of Agricultural Librarians and Documentalists

At a meeting in Frankfurt, March 1955, attended by agricultural librarians from seven countries and F.A.O., preliminary arrangements were made for the formation of this Committee, with the purpose of reviving and extending the work of the pre-war *Comité International des Bibliothécaires Agricoles*. Plans were made for the holding of an International Congress of Agricultural Librarians and Documentalists on 10 and 11 September 1955, probably at the Rijkslandbouwhogeschool at Ghent, at which the formal constitution of the Committee is to be followed by papers and discussion.

Anyone interested in making contact with the Committee is invited to write to one of the following addresses: Dr. S. von Frauendorfer, Hochschule für Bodenkultur, Vienna 18/110, Austria; Mr. Th. P. Loosjes, Centrum voor Landbouwdocumentatie, Rijkstraatweg 1A, Wageningen, Holland; Mr. D. H. Boalch, Rothamsted Experimental Station, Harpenden, Herts, England.

Diseases of Coconuts

E. B. Martyn
Late Plant Pathologist, H.M. Overseas Service

INTRODUCTION

The coconut palm (*Cocos nucifera*) is the major source of vegetable oil in the world. The area where it originated has been the subject of considerable argument among botanists, neither the evidence suggesting that this palm came from the old world, nor that indicating it to have been indigenous to the west coast of Central America or northern South America being conclusive (Burkill, 1935; Heyerdahl, 1952). It is now found throughout the tropics, cultivated and uncultivated, preponderantly near the sea, but also extensively inland. It grows on a multiplicity of soil types, and under annual rainfalls varying from the extreme to as low as 30 or 40 in. The seed and method of germination are well adapted to withstand long periods of drought, and the palm when established is remarkably hardy, individuals often living for years in the most unpromising environments and still producing a few nuts.

According to available statistics the world production of copra has recently approached three million tons (Commonwealth Economic Committee, 1953; F.A.O., 1951–1952), and must, in fact, be considerably greater than this as large areas of coconuts are not included in any returns from which statistics can be compiled. If we take as arbitrary but conservative figures 6,000 nuts to a metric ton of copra, and an average of 70 palms to the acre and 40 nuts per palm per annum, giving approximately 3,000 nuts per acre (Copeland, 1931), then six million acres of coconuts are required for the production of the copra included in the recorded returns.

Seen in this light the known losses due to diseases and pests appear negligible, the more so when related to the reduction in yields due to poor husbandry and planting sites that are far from the optimum required for good returns. On the other hand, in certain coconut growing areas epidemic disease has caused very serious loss, sometimes approaching 100 per cent. and there are a large number of minor diseases which take a steady toll. The cause of the epidemic diseases and of many of the minor diseases is still unknown and many commercial coconut growers would be glad to be able to forecast their occurrence and eliminate them from their plantations if possible.

In the Caribbean area, including British Guiana, and on the eastern seaboard of Central America, a number of serious coconut diseases cause considerable damage. These include red ring, a nematode disease of young palms, the ' unknown disease ' of the northern Caribbean, and the somewhat similar but distinct bronze leaf wilt of the southern Caribbean. The latter disease has recently been found to occur also in West Africa (Martyn, 1954). The two latter diseases have been epidemic in the areas where they have been observed, and it is possible that they occur elsewhere and have not been

recorded. In addition to these, the cadang-cadang disease of the Philippines and the mysterious root disease of Southern India have caused heavy losses. These last four named diseases, of which the cause is as yet unknown, are a potential threat to many coconut areas hitherto unaffected by them.

SYMPTOMS OF DISEASE IN COCONUTS

The coconut palm has but one growing point, and the death of the extremely well protected terminal bud must end the life of the palm. Much damage, however, and many abnormalities of growth can occur to the young developing tissues in the heart, or to the more mature leaves and inflorescences of the crown, without being fatal to the plant. The reactions of the heart and crown to unfavourable conditions or to pathogens can be many and varied. The pinnae of the leaves may merely change colour from a darker to a lighter green, or may assume varying shades of yellow or orange, or the tips and edges may become dried out, giving a scorched or withered appearance. Internal lesions, possibly the result of abnormal nutrition, and often found in both stems and petioles of coconuts, may result in breaking of the main rachis and consequent withering of the tip of the leaf, or the drying out of the pinnae over part of it. Sometimes localized lesions or mature leaves are associated with fungal damage to portions of these when they are emerging and still soft. One or more leaves may become malformed in the heart, never assume their accustomed form, and be followed by others successively less abnormal. The varying combinations of these features result in a wide range of symptoms, varying from those that persist throughout the life of the affected leaf to colour changes that may only be seasonal.

A healthy palm under reasonably good growth conditions will produce new leaves at the rate of about one a month, the oldest being shed accordingly, though under dry conditions, renewal occurs much more slowly. The crown of an average palm will contain up to three dozen mature leaves (Sampson, 1923). It is apparent, therefore, that many pathogenic symptoms observed in the crown of a coconut palm may be the result of factors that were active a year or more previously. Some symptoms may be transitory, but from others there can be no recovery. If, for instance, an annually recurrent water stress in a dry season scorches the pinnae of the outer and oldest leaves, these palms will always have a somewhat unthrifty appearance, whatever may happen during good growing periods at other times of the year.

The time factor and the difficulty of relating cause and effect, together with a number of abnormalities that can occur without proving fatal, result in unavoidable confusion in the accounts of coconut diseases throughout the world. Also, the similarity of symptoms arising in different parts of the world, from causes that are as yet unknown, has made difficult the naming of the various pathogenic conditions encountered. Descriptions of these often have to be made as a result of only one observation, whereas the slow progression of symptoms and their effect on the palm from their initial appearance to the final shedding of the affected leaves can only be adequately described when the observer is able to visit the palm at intervals over a long period, at least a year being generally necessary.

EPIDEMIC DISEASES OF COCONUTS

The only known lethal parasites of the coconut palm are *Phytophthora palmivora*, to which ' bud rot ' is attributed, and the ' red ring ' eelworm, *Aphelenchoides cocophilus*. The latter is believed to kill the palm by the toxic effects of substances produced by the nematode breeding in the stem tissues. Red ring may become epidemic in a plantation consisting solely of young palms, but is never so in an older planting, as fully matured palms in which the stem tissues have hardened are not affected (MARTYN, 1950).

Bud rot may be endemic in heavy rainfall areas, but only becomes epidemic following widespread hurricane damage. The writer is of the opinion that the fungus can only gain entry to tissues damaged either by wringing of the crown in high winds (not necessarily of hurricane force) or by other injury. This opinion may not be generally accepted, but it is to be noted that artificial infection has only been brought about after ' wounding ' the tissues, and that even when the fungus obtains a hold, recovery may occur, resulting in ' bitten leaf ' (BRITON-JONES, 1940). It would be interesting to discover if infection could be induced by *Phytophthora palmivora* in the heart of a vigorous and undamaged palm kept under humid conditions.

As regards the other known parasites of coconuts, the leaf parasites do not of themselves kill the plant, and the attacks of *Fomes* and related fungi associated with the death of palms in some parts of the world are not epidemic and are correlated with inimical factors of environment and senescence (Briton-Jones).

There are, however, four serious epidemic diseases of palms, the cause of which is as yet unknown, with which no parasite has yet been associated, and which fall into two distinct categories. The first of these includes bronze leaf wilt and the ' unknown disease '. Both these kill the palm within four to six months, and, in fact, the autolysis of the heart tissues, resulting finally in death of the bud, and also autolysis of the unopened inflorescences, is initiated within a month or so of the initial visible symptoms —nut fall and yellowing of the outer leaves (INNES, 1949; LEACH, 1946; MARTYN, 1945 and 1954). There are, however, certain distinctions between bronze leaf wilt and the ' unknown disease ', the former involving an earlier wilting of the older leaves, and the older nuts being often not shed. In the ' unknown disease ' the yellowed leaves remain turgid until the heart has died, and all the nuts are shed, though sometimes this symptom is initially unilateral (Leach). Palms replanted in affected areas succumb to the ' unknown disease ' again within two or three years, whereas ' bronze leaf wilt ' generally affects only older, bearing palms. The spread and occurrence of ' unknown disease ' is also more suggestive of a parasitic cause (MARTYN, 1949).

Bronze leaf wilt, first described in the Caribbean (Briton-Jones), has now been discovered in West Africa, its occurrence in southern Nigeria under the name of Awka wilt, and on the eastern seaboard of the Gold Coast under the name of Cape St. Paul wilt, being accompanied by symptoms almost identical with those of the southern Caribbean. A similar disease, but one less epidemic in its nature, has also been observed in French Togoland (MEIFFREN, 1951; MARTYN, 1954).

The cause of both of the above diseases is still a mystery. Bronze leaf wilt had previously been attributed to unsuitable physical soil conditions, but its occurrence in southern Nigeria throws a new light on the matter. In the first place it is found there on a friable porous sand to sandy clay of very considerable depth and in a rainfall forest zone. Therefore the unfavourable factors such as a heavy clay, impermeable subsoil, high water table or rapidly drying sand, all of which had in the past been speculatively suggested as possible causes of the disease, can be ruled out. Furthermore, there have been two distinct epidemics in this area, one of which wiped out the majority of the palms in 1916–17. This was followed by a 'fallow' period as regards coconuts, which are not grown in plantations here, but are scattered in village compounds. Planting was later resumed, and a second epidemic is now killing out all the 'new' palms aged 20 years or more. This behaviour, which has had its counterpart in the West Indies, does not suggest the presence of a residual soil parasite, which might have been expected to affect new plantings earlier.

All attempts to find a parasite associated with bronze leaf wilt have failed. The present evidence points to a cause related to the nutrient uptake, but the occurrence of what is apparently the same disease on such varying soil types as those of West Africa, and the West Indies and Guiana, suggests that more complex factors than the lack of a specific element are concerned, and the usual onset of the disease only after the palms are in full bearing indicates that the requirements of fruiting are in some way involved.

The 'unknown disease' also occurs on a very wide range of soils in the Caribbean, which again rules out a simple minor element deficiency as the cause, but no parasite can be found, and if the disease is due to a virus the symptoms are unique for a virus disease, and the habits of the vector, whatever it may be, are unusual. Further puzzling features about this disease are slight differences in its behaviour both in different areas of Jamaica (Martyn, 1949b) and in its appearance in Haiti and Nassau (Leach, 1946 and subsequent private communications).

The two other major diseases of coconuts that become epidemic are the cadang-cadang disease of the Bicol area of the Philippines, and the root disease of Southern India (Travancore-Cochin). These are only known to the writer from written descriptions (Kent, 1953; Varghese, 1934; Menon and Nair, 1951–52). They appear to have features in common, including a yellowing of the crown, the gradual dwindling in size of the leaves, and tapering of the stem. Nut fall and cessation of fruiting takes place in both diseases, but the decline of the palm is more gradual than in the case of bronze leaf wilt and the 'unknown disease', although death results eventually. The cause of these diseases also is still a mystery.

Root disease has been known in Travancore for over 70 years, and is being investigated at present by the Indian Central Coconut Committee. It is often accompanied by a condition of the crown known as 'leaf disease' which involves malformation of the leaves and from the description appears to have symptoms in common both with 'bitten leaf' and the 'St. Mary disease' of Jamaica (see below).

Cadang-cadang was first recorded in 1931, though what seems to have been a similar disease was reported in 1914 (Kent). It has been suggested

that this mysterious disease may be due to a virus, but in fact the true cause is still unknown and it is to be further investigated.

MINOR DISEASES OF COCONUTS

Many minor diseases of coconuts have been described from different parts of the world (Briton-Jones, Dwyer, Martyn, Varghese). Some, such as lightning strike, are of world-wide occurrence, others, such as the bacterial leaf blight described from New Guinea (DWYER, 1937) are only recorded from one area. There are, however, a large number of indeterminate diseases throughout the tropics which for reasons already indicated have proved difficult to name satisfactorily as their cause is unknown, but which from their descriptions appear to have many features in common and are probably the result of similar factors. St. Mary disease of Jamaica (Martyn, 1945) and maturation wilt of New Guinea (DWYER, 1937 and 1939) may be cited as examples both of which involve malformation of the crown that becomes evident in the maturing leaves; die-back of Jamaica (Martyn, 1945 and 1950) and quick taper of Ceylon (COOKE, 1950), which both involve withering of the older leaves, reduction in the size of the crown and pencilling, and are believed due to nutritional factors; frond choke of New Guinea and slow tapering of Ceylon (Cooke), all involving reduction in size of the leaves.

In addition to the above there are a number of diseases affecting the nuts. The ring disease of New Guinea (Dwyer, 1937) appears similar to the surface lesions of nuts described in Colombia and elsewhere (Martyn, 1949a), and splitting of husks accompanied by the oozing of gum is described from East Africa (Briton-Jones). Dwyer (1937) also refers to 'leathery kernel' in New Guinea. With none of these diseases is a definite parasite associated, though various fungi and bacteria can often be isolated from the accompanying lesions.

The shedding of nuts (Dwyer, 1937) and certain leaf stalk rots reported both in the West Indies and in Southern India (Briton-Jones, Varghese) are associated with *Phytophthora* damage, but the descriptions leave some doubt as to whether the fungus is acting as a primary parasite. Other minor troubles include stem bleeding, resulting generally from mechanical injury, various leaf spots, of which that attributable to *Pestalotiopsis* (*Pestalozzia*) *palmarum* is the commonest, thread blights (Briton-Jones) and distortion of the crown by insect damage.

In each of these diseases it is the influence either of the environment or of some mechanical factor on the coconut that is the essential factor, rather than any organisms which may appear to be related to the diseased condition. In some cases the causal factor is evident, *e.g.* excessive and prolonged humidity resulting in thread blights. In other cases, though the environment of the palm may clearly reveal a number of possibly adverse factors, the exact relation between these and the departure from normal growth has not yet been established.

NEED FOR RESEARCH

Coconuts hitherto have received less attention from agricultural research than the other major tropical crops. The Commonwealth, which in 1952

produced about a third of the world's recorded copra (Commonwealth Economic Committee, 1953), possesses two coconut research stations, one in Southern India and one in Ceylon, but the latter has had no cause to investigate diseases extensively, as these appear to be of little account there.

The reasons for this lack of investigation elsewhere are twofold. In the first place the crop is slow-growing, generally taking four to five years to come into full bearing, and sometimes a good deal more, and many of its diseases do not affect the palms until they are mature. The crop, therefore, does not lend itself to research, especially pathological research. Symptoms develop slowly and a tall palm is a difficult subject for detailed investigation, which often necessitates felling and consequent loss of the plant. In the second place, it is only in the areas where the effects of the epidemic diseases are very evident that the need for investigation seems apparent—and viewed on a world scale these areas so far are small. Ã serious threat to the total supply of copra has not yet developed. Possibly it never may, and the cost of the extensive research that might be necessary to combat these diseases may not therefore be justified.

On the other hand, the causes of the epidemic diseases of coconuts have remained mysteries since they were first recognized—in the case of ' unknown disease ' a hundred years ago, and root disease seventy. These puzzles cannot be solved by *ad hoc* investigations over a period of two or three years, carried out in the vicinity of the outbreak. The solution will not be found until a more fundamental study has been made of the botany of the coconut palm, with especial reference to its physiology and reaction to its environment under varying conditions, as it matures. A very long term and carefully considered research programme is required, to be carried out at an agricultural research institute in a coconut growing area where one of the major epidemic diseases occurs. It is essential to ensure continuity over what must necessarily be a prolonged investigation, and to have available the services of a number of different specialists, where varied knowledge and equipment might prove necessary as the work continued and different facets of the problem presented themselves.

In conclusion it is probable that if the mystery of any one of the epidemic diseases was solved, the solution of the causes of the others would follow more easily. Also, the knowledge gained from the type of investigation envisaged should help to explain many of the minor diseases of the palm. Most important of all, the practical application of the results obtained should enable a more accurate forecast to be made of the suitability of given areas for coconut planting, and the likelihood, or otherwise, of the epidemic diseases appearing there as the crop developed. This will be all the more necessary if practical remedies for the diseases prove lacking or uneconomic after their cause has been discovered.

SUMMARY

The widespread occurrence of the coconut is noted and figures quoted relevant to the world output of copra and the total acreage involved—over six million acres.

Reference is made to the major epidemic diseases of coconuts in different parts of the world.

An account is given of the general nature of the symptoms of disease in coconuts and attention drawn to the difficulty of satisfactorily describing and naming many of the pathogenic conditions recorded.

The known major parasites of coconuts (*Phytophthora palmivora* and the eelworm *Aphelenchoides cocophilus*) are shown not normally to cause widespread epidemic loss. The major epidemic diseases, of which the cause is not yet known and with which no parasite has been associated, are described. Four in number, they are shown to fall into two distinct categories, with two somewhat dimilar diseases in each, bronze leaf wilt and the ' unknown disease ' in the one, root disease and ' cadang-cadang ' in the other.

The minor diseases of coconuts are referred to, some of which appear to have been described under different names, though in fact much alike, and the majority of which are not primarily attributable to parasites.

It is indicated that only by more detailed and necessarily prolonged investigation of the botany of the coconut palm, and its relation to its environment and nutrient uptake as it matures, will the mystery of many of its diseases be solved. It is suggested, however, that if the cause of any one of the major epidemic diseases be found, then the explanation of the others will follow more easily.

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Aspects of Planning for Agricultural Development in North Borneo

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TOPOGRAPHY AND POPULATION

North Borneo comprises some 30,000 square miles of the northern tip of the island of Borneo, lying between approximately the fourth and seventh north parallels of latitude and roughly on the same longitude as Hongkong.

The country has a mountainous interior which culminates in the granitic mass of Mount Kinabalu, over 13,000 ft. high and the highest mountain in South East Asia. The mountain system is relieved by numerous river valleys and occasional plains, while the coastline is formed mainly of alluvial deposits. When undeveloped, the interior is covered with dense forests which constitute a most valuable economic asset to the Colony. The coastline usually supports nipa, mangrove and relatively low grade forests on soils ranging from clays to peat.

The climate is tropical with a daily average maximum temperature of 87° or 88°F, and heavy rainfall ranging from 70–150 in. or more per annum with considerable variation, even in localities only separated by a few miles, as a result of local influences on precipitation of convectional origin.

Agriculturally the Colony has much in common with territories adjacent to it, although with development it may well prove to have a richer heritage than many of them. Two areas in particular have interesting possibilities, the estimated 4,000 square miles of alluvial soils in the Kinabatangan river plains, and the rich volcanic soils of the East Coast Residency.

For present purposes, the population totalling about 335,000 with a density of 11·4 persons per square mile, may be divided into three major groups.

First, the Chinese. They number some 75,000 and dominate the townships, having a firm grip on the retail trade, while at the same time their land holdings in addition to producing a great deal of rubber, are an important source of fresh vegetables, chickens and eggs, pork, *etc.* More than any other people in North Borneo the Chinese understand and practise cash crop agriculture, as a consequence of which their production *per capita* and their standard of living is relatively high.

Secondly, the Dusuns and Muruts. Numbering together 136,590 people, they may be sub-divided into those who practise shifting agriculture and those who have settled on the plains. Practically all the Muruts and a considerable proportion of the Dusun people plant hill paddy and tapioca on the hill slopes of the interior. The cycle of cultivation varies considerably, permitting a reasonable regeneration of the soil in areas with low population density, but leading to the replacement of the original forest cover with poor scrub in other areas where population pressure necessitates the use of the

same land every few years. The headwaters of the Tuaran river are a case in point, where it would seem that only a movement of the hill peoples to less densely peopled areas can prevent more serious erosion than is already occurring.

Nevertheless, despite one's natural inclination to condemn shifting cultivation as being a most wasteful form of land utilization, it is probable that the practice in Borneo at least is much older than that of wet rice cultivation, which usually implies settled agriculture. Some of the forests of the interior are so remote and inaccessible that it is doubtful whether it will ever be economical to exploit the commercial timber in them and, provided the density of population amongst the hill people permits the fertility of the soil to be regained after each cultivation, it is difficult to see how any valid objections against the practice as such can be raised.

North Borneo, however, suffers from a shortage of unskilled labour, particularly on the east coast. At the same time it is physically impossible for medical services to reach many of the hill peoples in their small scattered settlements. Their ill-balanced diet renders them particularly susceptible to disease, while ignorance and detrimental habits occasion amongst them a very high rate of infant mortality, factors which are contributory to a decline in the numbers of the hill people, notably the Muruts.

Good administration cannot, as I see it, stand idly by and see the decline of these likeable people, and it is noteworthy that pilot schemes for the resettlement of people from the hills in areas more accessible to benevolent authority have been commenced. One such scheme has been particularly successful on the west coast at Binkor, where wet paddy is being grown, while on the east coast a four-year plan has been formulated for hill native resettlement for the Labuk area. Initially it is probable that full use may be made of the Agricultural Department's experimental farms such as that at Tuaran. Pioneers from selected hill villages will receive a training period after which they will return as agricultural missionaries to their own people, and it is hoped that later whole villages will move to the more fertile plain areas where land can readily be made available for them.

A particularly interesting feature is that the use of 'Kendingak', a quick-growing dry paddy with a high yield, is to be encouraged. This, although ploughing will be necessary to prepare the ground, does not require any expensive or laborious irrigation works nor involve any great change in agricultural techniques for the hill people. Hill people the world over are particularly conservative, and if in Borneo they can be weaned from shifting cultivation to settled cultivation of dry paddy with the possibility of rotating this crop with maize, ground-nuts, *etc*, in a gradual manner, there is reason for cautious optimism that they may gradually contribute much more to the economy as a whole, and by experience enjoy the benefits of civilization which, as yet, they may not actively desire.

Development planning for agriculture should, in my view, allow for very much more propaganda and effort being directed at the hill people. Nothing succeeds like success, the Binkor settlement and that at Kiulu in the Tuaran valley must already have considerably impressed the people who eke out a far more precarious existence in the surrounding hills. Extension work through all available channels should be continually pressed with a view to

resettling the hill people to their undoubted benefit, resulting in a gradual increase in production and a sounder basis to the country's economy.

Although our concern must be mainly with settled agriculture, it is logical to discuss the hill people and shifting agriculture at the same time. I must now make mention of the settled native agriculturalists, the Dusuns of the plains and river valleys. These Dusuns are a prosperous and stable peasant class and, while in recent times they have shown an aptitude for other types of employment, they are responsible for producing the great bulk of North Borneo's rice crop. Their production is usually limited to the extent of family requirements; in good years some surplus may be offered for sale, but only too often, in accordance with ancient custom, surplus rice and stock is consumed in large-scale village feasts and junketings. Hospitality is such that all and sundry are welcome to join in these feasts and tradition forbids the polite guest leaving until all is consumed. Rice beer brewed for these occasions undoubtedly supplies an important contribution of Vitamin B to native diets and cannot therefore be altogether decried, but moderation should enable them to sell much more produce for cash with which to raise their living standards and enable them to purchase over a period other necessities of a balanced diet.

The third group of peoples are the coastal dwellers who are Muslim by religion, including the Bajaus, Bruneis and Kadayans. From their ranks were drawn the pirate crews of older times and many of them are still seafarers and fishermen. Prior to the development of a true money economy, they fulfilled, as they still do today, an important function by trading their fish for the rice of the Dusun farms, giving protein, of which they had a surplus, for carbohydrates which they were short of. Under more settled conditions their numbers are increasing rapidly and more and more they are adopting agriculture as a means of livelihood. Land had no value for them in the days when their frontier was bounded only by the horizon, but now many have taken to paddy planting, especially the Bajaus at Kota Belud and the Kadayans and Bruneis in Papar District. Being of more temperate habits than the Dusuns, they frequently become prosperous more quickly and invest their wealth in herds of buffaloes and improved houses. It is probable that the Muslim people will wish to take up very much more land in future. They still prefer to live near the sea or on rivers and are unlikely for some time to become pioneers developing new lands further towards the interior. It is noticeable that there is frequently keen competition for land between Dusun and Bajau or Brunei on the coastal margin, and at least one village, to my knowledge, is now predominantly Brunei and Bajau which was previously Dusun, indicating the desire and ability of the Muslim races to gain a foothold on the land.

RICE CULTIVATION

The most important crops grown are rubber, rice, coconuts, sago and tapioca, while for local consumption a great variety of fruit and vegetables is grown. Native grown tobacco is widely smoked by all races and is manufactured into very tolerable cheroots. At Segama on the east coast, a large European-run tobacco estate produces some of the finest cigar wrapper leaf in the empire, while there is every hope that Manila hemp

which has been planted on a large scale in the Tawao area may prove to be an important addition to the Colony's agricultural products and an important dollar saving export crop.

In a world situation where the growth of population, particularly in areas where rice is the staple food, is almost alarming, the importance of food crops cannot be over emphasized, and I therefore propose to deal at length with paddy cultivation in this paper, giving it priority over the Colony's main export crop, rubber. It will be seen that the measures I would advocate to improve existing production of paddy in particular must necessarily have a marked effect upon agriculture generally, indeed, all aspects of agricultural development would seem to hinge upon the staple food crop. The Colony is at present dependent upon supplies of rice from overseas, notably from Siam, in order to feed the population adequately. The degree of self-sufficiency varies from year to year depending upon the success or failure of the domestic harvest, but from the fact that in the years 1947–50 inclusive, imported rice cost the Colony an average of over four million dollars per annum, it is apparent that the deficiency is considerable.

Nevertheless, in good harvests, production figures per acre of paddy compare favourably with those of neighbouring territories, being of the order of 1,500 lb. per acre. I do not think it is reasonable to hope for sufficiently increased production from the existing acreage to offset the present deficiency, no matter what improved techniques are embarked upon.

It has been found elsewhere that manuring will raise the yield of paddy by 15 or 20 per cent per acre, but at the same time the financial return is not commensurate with the cost. The average increase in paddy yields on test plots sown with selected seed in Malacca was 23 per cent. In Borneo, too, no doubt something can be done by selecting within native types of seed, by introducing more productive types from other areas where similar conditions prevail, or by developing new types of paddy adapted to prevailing conditions. These solutions to the problem are long range ones, however, and not susceptible of implementation by the North Borneo paddy grower by his own efforts, nor in any case can we conclude that either manuring or improved seed, or both, will produce spectacular results on a scale materially to effect the overall paddy production within a reasonable period.

Bearing in mind increasing domestic demand as population increases, these measures can be expected to ameliorate, not to remedy, the situation. Plainly, then, the solution probably lies in expanding the acreage devoted to paddy cultivation.

In the typical paddy growing areas of North Borneo, it is common to find stretches of flat open paddy land surrounding the villages comprising perhaps 500 acres or more. These areas are composed of many contiguous individual holdings of land ranging from quite small sub-divisions of an acre to perhaps as much as 10 acres, with very occasional exceptions exceeding 10 acres in area. Land registration is under the Torrens system and the individual farmer knows his land boundaries by virtue of the boundary pegs emplaced during its survey and demarcation.

It is of the utmost importance, I would submit, to consider in conjunction with the paddy farmer's land, the buffaloes he needs to plough it.

During the planting season all open paddy lands are rapidly ploughed up and planted by the individual owners. Usually this is completed within two months, the actual dates varying in different localities by reason of local rainfall peculiarities. Thereafter, dependent usually upon rainfall for irrigation, and upon the sun to ripen his crop, the farmer weeds his land at intervals, and in about six months' time commences harvesting. Where gravity feed irrigation from streams is possible this is often practised with ingenuity, but no artificial means of irrigating land comparable to the ancient practices of Egypt, India and China have been evolved by the peoples of Borneo.

Cultivation having been completed, the buffaloes which have been used for ploughing and harrowing the land are naturally denied access to the area of growing paddy. While it has been lying fallow, however, this land is usually their chief source of grazing, so that it follows that during the planting season grazing land for them and, indeed, for all animals, decreases by exactly that area which is under paddy. Areas of land have been set aside by Government as grazing reserves, but not infrequently the reserves consist of land unsuitable for agriculture and therefore unlikely to produce good grass, or again they are so distant from their villages that farmers dislike sending their animals so far away from personal supervision, and endeavour to tether and graze their animals on roadside and riverine margins.

It is not surprising that during the season when they are denied access to the more fertile areas buffaloes tend noticeably to lose condition, and unless optimum conditions of heat and rainfall permit maximum growth of food for them on the poorer areas to which they are consigned, loss of condition is very marked and considerable mortality can occur.

This apparent digression on the buffalo may be justified in that the animal is essential to the cultivation of paddy and his welfare should be of primary importance to the farmer and given every consideration by Government.

Since the paddy field pattern resembles so closely the old open field cultivation system of feudal England, insofar as physical boundaries between individual plots of land consist only of the low bunds made by the farmers to trap and conserve water for their paddy crop, and since grazing reserves have, at best, a surrounding fence, there is normally no restriction whatever on the free range and intermingling of all animals. I have only come across a single farmer in North Borneo who regularly castrated unwanted male animals and selected the best bull calves for breeding purposes. Under these conditions selective breeding is non-existent and impossible, except insofar as the more virile animals may tend to dominate the herds, and poor physical types must often be procreated when female stock is served by any of a wide selection of animals from the common herd.

The majority of farmers own perhaps two, three or four acres of paddy land for which they pay a low annual rent to Government. Land originally issued to farmers in holdings of reasonable size has often been sub-divided especially as a result of the rules of inheritance amongst the native people. G. C. Woolley, commenting on Dusun tribal custom, writes of Papar District ' All children, sons and daughters, can claim a share in any land left by the deceased if there is enough to go round, but infinite sub-division is not allowed; sub-division stops when smaller sections could not be worked

economically '. There is no doubt at all that fragmentation of land holdings proceeds beyond the point at which sub-divisions are economic units. Native customary law, though dynamic, has come to us from an era of subsistence economy not based on cash.

The average farmer, in answer to a query in regard to his land holding, usually says he has ' Chukup makan sahaja ', implying sufficient land to feed his family. Thus, while in good years he may have some paddy surplus to his needs, more normally his planting and harvesting functions occupy only four months of the year and he is dependent on money earned elsewhere for all his cash needs. He is virtually a part-time farmer by our standards, and at this point I may summarize certain conclusions which may be drawn from our survey.

First, that an increase in paddy production to a point at which the Colony will be self-sufficient can only be achieved through considerably increased acreage.

Secondly, that the pattern of paddy farming as it now exists is particularly detrimental to animal husbandry.

Thirdly, the majority of holdings are uneconomic in size, enforcing mere subsistence agriculture on their owners.

Let us consider the possibilities of planning for an increased acreage under paddy in the light of what economists would have us believe to be the essential factors of production: land, labour and capital.

On the first point, land already developed for agriculture of all kinds only amounts to a small fraction of the Colony's total area.

At the same time that land hunger is apparent in areas like Penampang, where all flat land has now been taken up for paddy cultivation, the west coast still has relatively large areas of potential paddy land undeveloped. On the east coast, if accounts are not over-optimistic, it would seem that the Kinabatangan basin awaits only persistent human endeavour in land clearance to become eventually one of the so-called ' rice bowls ' of Southern Asia. Suitable land is certainly not in short supply.

Unskilled labour for many purposes is in short supply, but my contention is that there is, in fact, concealed unemployment in agriculture and that on its present subsistence level the best possible use is not made of the labour available.

In elaboration of this point, we have seen that the majority of farmers complete the planting and harvesting of their paddy very quickly. It is most noticeable that in the rare larger holdings ploughing and preparation of the whole area takes much longer, so that the farmer finds it necessary to stagger the sowing of seeds in his nurseries. He may also find it necessary to plant early and late ripening varieties of paddy so that the demand for labour to harvest his crop can be spread over a long period rather than prove difficult to meet in a brief period when all his crop is ripe at the same time.

If land holdings were bigger generally, then in general the planting and harvesting seasons would tend to be extended and agricultural workers more efficiently employed, so that the same force of labour already employed in agriculture could produce much more rice.

It is, of course, true that I have mentioned a shortage of unskilled labour for other purposes in the Colony, and if more man-days are spent in harvesting and planting paddy, this shortage would tend to be more acute, but this serves only to emphasize the type of dilemma in which a planning authority anxious to give priority to a single aspect of development can easily find itself. One answer is, that with a larger area of land, more farmers would have a marketable surplus of produce from the sale of which living standards could be expected to rise, and therefore mortality would fall as a result of improved homes and diets, *etc*, and thus eventually more labour would be available.

Capital requirements for the development of new areas depend very largely on their location. In general, readily accessible land has already been settled, and marginal agricultural land in North Borneo is not necessarily that which is less fertile, but that which is more difficult of access.

Where contiguous expansion of cleared paddy land is possible, settlement on the fringe is continuous as more and more land is required. Where, however, areas suitable for paddy land are separated by stretches of country difficult to negotiate and usually sparsely inhabited and devoid of roads, it is much more difficult to induce new settlement. Moving becomes, as it were, a leap in the dark necessitating the carrying in of all the food supplies required until the first harvest is taken. The pioneer settler in a new river valley will probably have an inordinately large number of wild animals and pests to contend with; he knows that he can only market his surplus produce, if any, with great difficulty, and he is remote form all normal amenities.

Roads are an expensive luxury, but while North Borneo requires to spend large sums of money annually on the expensive necessity of importing rice to feed its people, plainly, roads, which encourage the agricultural development of new paddy producing areas, would be one of the soundest possible long term investments of capital.

Financial assistance directly to farmers in new areas would only need to be comparatively modest; some assistance in the purchase of barbed wire for fencing purposes, implements and interim food stocks could be provided for individuals requiring it in the form of small low-interest loans, repayable after a period sufficiently long to enable the settler to find his feet.

While it is difficult to see how the productivity of agriculture can be greatly increased in the fully settled areas, where by law all land allocated for paddy growing is already fully planted annually, development planning should be able to do much in areas as yet undeveloped, and I would suggest that at least a fair trial should be given to a revolutionary type of land holding.

In an uncertain world situation, the Government introduced in 1949 a paddy purchasing scheme designed to buy up paddy from districts producing a surplus in order to create a central food reserve. This scheme quickly gave the Colony a valuable reserve of food at a time when rice was not always easy to acquire on the world market. Later, in 1952–3, as an inducement to growers to sell their surplus paddy to the Government, so-called inducement goods, including barbed wire, were offered to farmers in exchange for paddy at an exchange rate comparing favourably with the

cash price for these goods demanded by local shopkeepers. It was a popular innovation and led to a great increase in the number of fenced holdings, barbed wire being particularly sought after.

As a result of fencing, one farmer, who divided his land into two areas, told me that he had been amazed to notice how well the grass recovered in one section of his land while his buffaloes were grazing in the other. In fact, the value of rotational crops had become apparent to him almost overnight. Whilst his land was fallow, his animals could enjoy better grazing on a restricted area than they could possibly find on the overgrazed reserve areas, and were segregated from the common herd under his close personal supervision.

I consider that full experiments should be made of integrated farm units on the pattern with which we are familiar in Britain and that future alienation of lands under Native Title should comprise much larger areas than are now usually applied for and allowed. Moreover, on such new farms the compulsory planting up of the whole area with paddy should not be continued.

If we suppose that a farmer requires four acres of land for the support of his family, then it is reasonable to add a further two or three acres of land on which he can produce a marketable surplus of paddy. Suppose further that he requires three or four buffaloes for ploughing purposes, and assume that on an average one acre of land will support one buffalo, then at least four more acres should be added for grazing purposes. A house, garden, pig-sties, fruit trees and other crops would probably require more room, so that a reasonably economical size for his holding would be 12 or 15 acres rather than three or four as is now often considered to be the case.

I have already argued that most farmers could plant larger areas with paddy if they devoted more time to it, and therefore a condition of a larger holding such as I suggest could still be that a given proportion of it, say half, must be fully planted with paddy each year.

While land is issued under Native Title, as at present in usually small parcels for paddy planting, and must by law be fully planted up each year, mixed farming which would place the agricultural economy on a sounder footing is out of the question, rotational cropping is impossible and productivity so far from increasing should logically decline as successive crops are taken from the same soil each year without any attempt to renew fertility.

In considering new areas in which to extend the acreage under paddy, regard should be had to the peculiar response of the rice plant to a wide range of climate and, more especially, soils.

In his excellent book on rice, J. H. Grist states that as compared with water supplies, soils are relatively unimportant to it. Rice is, in fact, grown successfully on a wide variety of soils, both light and heavy, acidic and neutral, while even most unpromising soils may be built up into suitable rice-growing media by cultivation and manuring. Paddy soils very dissimilar in chemical composition yield equally good paddy crops, and his conclusion is that chemical analysis of soils does not appear to provide any very sure guide as to their suitability for paddy.

This is of particular interest to us in an age when development plans tend largely to feature the advice of experts, and there is something pleasing

in the thought that in respect of the rice plant, the guess of the primitive farmer when prospecting a new area is just as likely to be good as the calculation of the soil chemist.

The contention of Grist is that while again the effects of manure on paddy are so complicated that it would be unwise to be dogmatic about it, and although paddy has been grown successfully for hundreds of years on the same land without rotation, this does not mean to say that both manuring and some form of crop rotation would not prove to be beneficial.

My contention is that larger farms making mixed farming possible would certainly make crop rotation possible, while the enclosure of draught animals would replace in some degree the fertility of the land as well as enabling selective breeding to be practised.

MECHANIZATION

In my analysis I have not as yet considered the part which machinery may have to play in increasing and making more efficient the production of rice in North Borneo.

As regards cultivation, the substitution of tractors, tractor fuel, trained drivers, mechanics, the supply organization of replacements and spare parts, and advisory supervision for ordinary native farm labour would mean, in effect, the substitution of costly for relatively cheap factors of production.

The cost of these expensive factors of production would tend to be inflexible, whereas crop yields and prices tend to be highly flexible. One farmer with 40 years' experience of paddy cultivation told me he had found that, over a period of years, on an average one year in three produced a first class crop, one year an average crop, and one year a very poor crop.

In the United Kingdom tractors average 800 to 1000 h work per annum. The average farm in North Borneo, other things being equal, could be ploughed in a few hours so that any future for mechanical cultivation would seem to lie in the organization of special contracting units, rather than in individual ownership.

No doubt in the use of machinery for milling, for the construction of dams and for the pumping of water for irrigation, very much can be done, but before any conclusions can be reached there is room for much experiment. Factors such as the selection and trial of suitable types of machinery, the supply and repair services, the training of operators, mechanics, *etc*, and workshop and servicing arrangements require careful study.

I consider that there is very little scope for mechanization in areas which are already intensively cultivated in North Borneo, especially since some sort of land reform might well be a prerequisite in order to group lands into economically workable units for mechanical cultivation.

Machinery under suitable conditions may well be used in order to accelerate the opening up of new lands. The use of mobile band saws, tractors for grubbing and hauling trees, the winching out of stumps and roots are obvious possibilities. Nevertheless, one has to remember that many potential paddy growing areas are uncleared swamp land. It is unlikely that machinery will be useful in these areas unless modern engineering methods can solve the problem of ' floating ' the tractive power units and still retain their mobility.

From considerable experimental work in Malaya the conclusion has been reached that the mechanical harvesting and threshing of paddy is unlikely to save very much time, and that very effective control of irrigation water is necessary before really effective use can be made of machinery for cultivation.

Experiment has shown, however, that with mechanical ploughs one problem is often that of ploughing to the correct depth. It would seem that conditions may vary in different localities, and on different soils, since in North Borneo there is reason to believe that deeper ploughing than that now generally practised may be beneficial to paddy cultivation, whereas in Malaya deep ploughing has, on the whole, been unsuccessful.

Until the difficulties of using machinery in swamp lands have been overcome, the best possibilities for its use will be found on hard pan soils such as are not uncommon on the clay soils of North Borneo's west coast.

Development planning for agriculture in North Borneo should allow for a careful study of the experimental work which is progressing in Malaya under similar conditions of soil and climate, rather than consider embarking upon a similar and no doubt expensive series of experiments within the Colony. Indeed, it might be a sound investment to support Malaya financially in her mechanical experiments in order to benefit from the lessons already learned. It is interesting to note that it is already possible on Malayan experimental stations to tackle the mechanical cultivation of paddy under more difficult conditions than was thought to be possible even comparatively recently.

There are two further points which should be carefully studied by the Government. First, there is the question as to whether, in fact, the achievement of self-sufficiency in rice is an economic proposition. If ample and reasonably cheap supplies of rice are forthcoming from overseas, it may well pay North Borneo to channel the factors of production otherwise used for paddy cultivation, into the development of other resources, into expanding the rubber and timber industries, for example, or perhaps to switch them to new crops such as pepper and hemp, if it can be seen that in doing so proceeds from the sale of these products will easily buy sufficient rice for the Colony and win for the Colony's economy a securer position than could otherwise have been realized.

Secondly, in a country where the margin of deficiency in domestically produced food is comparatively small, as in the case of North Borneo, a most difficult position could occur if, following a steady expansion of paddy acreage, the colony suddenly found itself with a surplus of this commodity and had no marketing organization in existence to cope with the situation.

Government intervention in North Borneo in paddy cultivation already takes the form of assistance to growers by irrigation and drainage projects, preferential rents, the provision of seeds and technical advice, *etc.* At least one road is under construction into an undeveloped area where considerable areas of land are suitable for paddy growing. It is certain that no difficulty whatever will be found in finding settlers to develop the lands adjacent to this road, and a real increase in the area under paddy in this locality should soon be apparent.

In my view, the best means of achieving the additional acreage of paddy

required to secure self-sufficiency lies in building more roads of this nature, promoting mobility of population as did the roads and railways of Britain over one hundred years ago. People must be induced to occupy and clear more and more marginal land, and there is little doubt that accessibility will be the primary consideration by which the average settler will be induced or dissuaded from moving to new areas.

DIETARY IMPROVEMENT

Having considered the staple food crop at some length, it is relevant to consider the normal diets of the people in North Borneo so that the part that agriculture can play in their improvement may be considered.

In general most diets have a quantitative sufficiency, but have qualitative defects and are bulky as compared with their nutritive value. The Chinese section of the population, with higher living standards, tend to enjoy very much better food than do the natives. They are well aware of the need for special care of the mothers' diet during and especially after pregnancy, and it is not too much to suppose that the comparatively low rate of infant mortality amongst the Chinese, and their general fertility, are directly attributable to these factors.

Amongst all sections of the native community diets are generally very ill-balanced, being especially low in proteins derived from animal sources and vitamins. Malnutrition walks hand in hand with ignorance, and while there is often an apparent lack of actual fertility, there is also considerable infant mortality directly attributable to wrong feeding and to the lack of elementary knowledge of hygienic methods during and after childbirth.

The lack of vitamins, together with the lack of calcium in diets, has been advanced as a cause of the low degree of fertility among the Hausa women of Africa. In his book ' The Tropical World ', Pierre Gourou suggests that the habit of eating earth, which may frequently be observed among the native women in North Borneo, is due to a subconscious desire on their part to obtain more of the phosphorus, calcium, iron, iodine, and sodium in which their diet is deficient. A rise in the standard of living should result in the consumption of food richer in protective nutriment.

There is a most marked difference in the size of Dusun families between those on the Papar plains where the standard of living is relatively high, and in those found in the foothills of the Crocker Range. It can indeed be argued that they have access to medical services and may have a percentage of Chinese blood as a result of intermarriage, but infant mortality apart, they unquestionably have more births per family and there is but little doubt that they have copied an improved diet from the Europeans and Chinese and benefit thereby.

Ill-fed people, weakened particularly by intestinal diseases and malaria, cannot be expected to become the most efficient farmers, and the low yield of their labour in a vicious circle, is reflected finally in their diet.

Obviously there is scope for much endeavour by the Agricultural Department in conjunction with health authorities. The health authorities can point out the deficiencies in the general diet and the Agricultural Department can consider how they may best be met, always remembering that the desirable must be conditioned by the practicable.

Nevertheless, it is, I think, arguable that larger farms, only a portion of which have to be compulsorily devoted to paddy, would encourage and make mixed farming possible. A more mixed farm economy should do much to improve the balance of native diets and lead to a greater use of animal protein. It is most interesting to note that some native chiefs have already advocated the compulsory planting of vegetables by their peoples. Such a measure requires much consideration before it may be adopted, but I can see no reason why one or two acres of a farm of twelve acres or more, say, should not by law be devoted to the cultivation of soya bean, groundnuts, green leafy vegetables and more fruit. Certainly succeeding generations could be expected to be of finer stature and capabilities if such a measure enabled more correct feeding habits to be introduced on a considerable scale.

My conclusion on this point is that improvement in health must go hand in hand with proper utilization of the land. It would be a practically impossible task to improve to any considerable extent the health of the scattered population in the hills pursuing shifting agriculture, and the health authorities have tended very properly to focus their attention in North Borneo on areas moderately densely peopled. I have already shown that I do not consider that the land in the adequately settled areas is necessarily utilized to the best advantage, but areas of new settlement should provide the opportunity of modifying and adapting land utilization practice in a manner which would be complementary to measures for improved health spreading out from settled areas.

The Anchau development scheme in Nigeria provides an interesting example. Here it was found to be impossible to cure a scattered population of sleeping sickness; the authorities concentrated the people in part of the district and settled them on an improved system of land lay-out and utilization, with most beneficial results.

SOIL PROBLEMS

In dealing with rice cultivation, I have mentioned some of the plant's peculiar characteristics and have been chiefly concerned with wet or swamp rice, for which, as we have seen, a good water supply is more important than a good soil. For this reason, the question of the general fertility of North Borneo's soil has not arisen beyond the need for brief introductory comments, and I must now explain its characteristics in more detail.

Man would never have developed the technique of shifting agriculture if he had found that a single clearing in the forests would provide repeatedly good series of crops. As we know, he is constantly forced to move elsewhere because the areas he clears and cultivates very quickly lose fertility.

In general, the soils of North Borneo correspond closely to those found in Malaya and other areas with a hot wet climate. In forested areas the luxuriance of the vegetation conceals the fact that soil fertility is in a state of equilibrium. The forest feeds upon its own organic matter, in conditions of optimum heat and rainfall, promoting ceaseless renewal of growth. Far from indicating remarkably rich soils beneath them, giant trees are often found to be supported on poor, leached, soils. The removal of the forest cover at once upsets the balance, percolating water after torrential

rain carries away all soluble bases and nitrates aided by the high temperature, acids, and the very rapid bacterial action to which the climatic conditions are so favourable. Unlike the temperate zones, where chemical and biochemical action do not penetrate nearly so deeply, in the hot wet tropics fertility is readily destroyed to considerable depths. The rise in surface temperature following exposure to the sun leads to a heavy waste of nitrogen. The soil surface is subjected to great variations of dryness and dampness and in these conditions the oxidation of humus is very rapid indeed.

Exceptions to the generally poor nature of the soil are to be found in the volcanic soils of the East Coast Residency and in alluvial deposits of eroded topsoil which have not had time to become poor.

The violent tropical rainstorms not only inhibit the absorption of water by the soil, by choking its porous openings with fine impacted silt, but scour all surfaces unprotected by vegetation, and sweep the more valuable top soil away to the river. Wherever overgrazing on the hilly areas of grazing reserves has occurred, considerable soil erosion is apparent in North Borneo, a feature which is particularly noticeable from the air, and once the top soil is gone, a compact and sterile soil hostile to agricultural endeavour is left.

In general, erosion is not a problem likely to arise on level tracts of land. In swampy areas the commercially valuable sago, nipa and mangrove all perform a valuable function in helping to fix soil eroded from hill slopes elsewhere and carried in suspension by watercourses and streams. The water conservation methods practised by paddy farmers inhibit erosion, while areas of plain unsuitable for paddy cultivation usually have a permeable nature enabling even the heaviest of rainfall to be quickly absorbed in the soil. The agricultural future of such usually sandy areas would seem to lie in the cultivation of groundnuts, tapioca and similar crops such as sweet potatoes, which apparently are not averse to sandy soils provided rainfall is sufficient or water can be provided by irrigation.

The problem of conserving the nutritive values in the soil arises very much more on hilly lands where the forest is cleared for the cultivation of rubber. Only the most careful terracing and water control can prevent permanent damage to the soil, the physical removal of it and loss of its fertility. A most noticeable feature on one rubber estate I observed was the poor quality of the growth on all the ridges and hill crests of the estate. This was undoubtedly attributable to the clean weeding practice formerly observed by rubber growers which enabled the heavy rains to leach and scour the topsoil, while it was at the same time fully exposed to the sun's rays, until the rubber trees had attained sufficient size to provide their own shade cover.

It would seem that all newly cleared ground should be planted with some quick growing crop such as maize or even dry paddy as soon as possible in order to stabilize the soil and minimize, or at least retard, the effects of oxidation. It is again noticeable that where native smallholders take a quick crop of paddy from land cleared for rubber planting purposes, the rubber seems to do well since the soil is protected by the roots and stubble of the paddy and the weeds which accompany it.

CASH CROPS

Most smallholders with experience of the remarkable fluctuations in price which have been a feature of the rubber industry, consider even today that the crop is worth growing since one good year in ten may amply reward them for the relatively small amount of maintenance the trees require during periods when the price is low. North Borneo will undoubtedly continue to be largely dependent upon the income derived from the sale of rubber abroad for many years to come. In times of scarcity and therefore of high prices, the production of large quantities of synthetic rubber is likely to be encouraged since, unlike natural rubber which comes into bearing only after about six years, synthetic rubber can be made available in quantity after a relatively short space of time. Other things being equal, however, it would seem that the proper role of synthetic rubber is to act as a stabilizing factor in the natural rubber industry, which it is most unlikely to supersede entirely, by preventing or at least counteracting too violent price fluctuations. Unless its production can be achieved with small costs, natural rubber should be able to compete very effectively.

To ensure this, obviously, natural rubber production must be conducted as efficiently as possible. In North Borneo, where labour to tap and develop increased acreage under rubber is not likely to be readily available, the answer may well be found in the reverse process. The older less productive trees should be replaced by high yielding varieties which would enable overall production to increase on a reduced land area, thus making for more efficient use of the available labour. It would seem that a careful replanting programme on these lines would be a sound investment and one worthy of Government encouragement.

Wherever there is a competitive demand for land between rubber and food crops, particularly rice, then in pursuance of existing Government policy priority should be given to the food crop. Examples of haphazard development in the past may be observed in the very indifferent rubber plantations which may be seen in some areas on land which would undoubtedly be very much more productive under paddy. In general, development planning should not permit the planting out of flat land with rubber at the expense of rice.

For the future, North Borneo might well endeavour to broaden the basis of its agricultural economy, notably by expanding the production of hemp, tobacco, and especially pepper. There would also appear to be no reason, since both coffee and cocoa have been grown experimentally, why very much more land should not be devoted to their production on a commercial scale. The Irish potato is already grown by the natives on the uplands of the interior, but the product is, in general, small and can be obtained on the Coast at high prices only, due to the necessity of lengthy transport by pack-animal or native porter. It would appear that improved seed, manuring and better techniques might do much to increase current production and to improve the product while, in due course, improved communications should facilitate marketing. These upland regions might also be very suitable for tea growing and there is undoubtedly much room for experiment

with the highland areas, so that their potentialities may be known and developed as the communication network gradually reaches them.

LIVESTOCK

It is in these areas that North Borneo may be able to develop beef production. I am told that in Jamaica improved breeds of cattle imported from the temperate zones are successfully conditioned to the climate by a quarantine period which is spent at an altitude which reproduces a cooler climate. It is probably too much to hope that pedigree cattle from Britain would thrive at sea level in Borneo, but no doubt they would have a better chance at an altitude which provided a more temperate climate. Moreover, there is no doubt that much could be done to improve existing local cattle by selective breeding and by crossing with the most suitable cattle from elsewhere.

A ranching experiment is now being conducted under the C. D. & W. scheme, on scientific lines and with controlled grazing, with the intention also of importing improved breeds to upgrade the local stock in due course, so that in the long run it may be that North Borneo will be able to emulate the achievements attained in the Kenya Highlands and develop her own dairying industry.

Improved breeds of pigs have already been imported, and since both Dusuns and Chinese produce large numbers of pigs, the improved strains should do much to increase the amount of pork available for local consumption.

Goats are noticeably increasing in numbers, and although they are not used to supply milk, their importance lies in the fact that they are both acceptable to the Muslim peoples and can browse on the jungle fringes, finding sustenance where grazing animals could scarcely be supported. They may serve a particularly useful purpose amongst the shifting agriculturalists, whose protein intake is adequate only on rare occasions.

As the people of North Borneo learn by experience and education the merits of improved diets, Government should be particularly careful to ensure that tariffs on the import of foodstuffs which would help to remedy dietary deficiencies, such as milk in particular, are kept to a minimum, while at the same time the efforts of agriculture within the country are directed along the lines suggested.

CONCLUSION

The complex nature of the general situation can be readily perceived even from so cursory an analysis, and in particular the interdependence of all government departments is clear. Viewing the whole field of agricultural development, however, and considering the problem of priorities, whether, for example, more emphasis should be given to education before a campaign of agricultural extension work is embarked upon to introduce beneficial innovations in all the many aspects of farming techniques, I am drawn irresistibly to a personal conclusion that a fundamental objective on which all development planning should rest should be the development of a much improved communication network.

It is perhaps not insignificant that the greatest strides made in agriculture

in Britain depended not only upon the experiments of those who improved the breeding of animals, and discovered the value of manuring and so on, but on the equally important work of Telford and Macadam and the railway pioneers.

In North Borneo where, in any case, inter-village raids for heads developed a particularly parochial outlook amongst the people, new ideas are only likely to spread effectively when the difficulties of travel through swamps and forests have been removed by modern communications, and the farmer can readily see what more enlightened people are doing elsewhere, can market his crops with the minimum of effort, and can move freely to new lands if and when he discovers the possibilities of farming commercially, and wishes to move from his ancestral subsistence farm to broader acres.

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Locust Reporting and Anti-Locust Research

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For many years, information on the occurrence and migrations of locusts has been collected in tropical and subtropical countries of Africa and Asia and forwarded to the Anti-Locust Research Centre in South Kensington, London. An extensive reporting system has been built up and steadily improved in the course of time, so that nowadays, with greater speed of communication and with international co-operation, the Centre has a fairly accurate picture at any particular time of the overall situation in the whole of the vast area liable to be occupied by the species of locusts with which it concerns itself.

During periods of locust plagues, which may last for several years, reports of locust activities reach the Centre daily, and in the course of a month information may be received from some 30 different countries. Every record of a locust swarm, hopper band (*i.e.* aggregation of young locusts in their non-winged stages) or egg-field is separately plotted on a map, and subsidiary information, such as direction of movement (in the case of swarms), degree of sexual maturity, estimated size of swarm or hopper band, and stage of development (in the case of hoppers) is considered in relation to the general situation. If more than one species of locust is involved, each is recorded separately.

The purpose of this reporting system is twofold. The immediate object is to enable the Centre to prepare each month a brief account of the current situation and to forecast from it and from the accumulated experience of many years the changes that are likely to occur in the next few weeks, especially with regard to direction of migration, probability and siting of large-scale egg-laying, and the appearance of hopper bands. These summaries and forecasts, which are despatched monthly to all interested countries and organizations, serve to give warning of impending developments and dangers in time for preparations to be made to meet them. This is a service which is of obvious immediate value in relation to current affairs.

The second object is to provide a basis for all branches of locust research, with a view to acquiring ultimately a full understanding of the locust problem as a whole. All lines of research designed towards this end, depend directly or indirectly on thorough knowledge of the geographical and climatological aspects of the occurrence, distribution and migrations of the different species separately.

The Anti-Locust Research Centre, while interested in all harmful species of locusts and grasshoppers, is mainly concerned with three; these are the Desert Locust (*Schistocerca gregaria* Forsk.), the African Migratory Locust (*Locusta migratoria migratorioides* R. & F.) and the Red Locust (*Nomadacris septemfasciata* Serv.). During the period of time for which continuous records are available, plagues of two of these species, and not always the

same two, have sometimes occurred simultaneously, so that any study of locust activities, especially migrations, is complicated by the need for reliable identification of the species for every record utilized. In the earlier years of the period, the species was often not recorded, and in such cases the information that is available must either be discarded or be considered in relation to what is definitely known of the activities of the different species at that time in the hope that virtually certain identification may be possible by inference. The sifting and analysing of all the worth-while past records has been perhaps the most important contribution so far made towards the solution of the locust problem. This work has in itself constituted a major research project, and its results, in association with those of exploratory entomological and ecological field work in many countries and by investigators of several nationalities, have already led to understanding of the broad geographical and seasonal aspects of the breeding and migrations of the three species mentioned. They have also made possible the creation of two organizations, each established on a firm international basis, for the purpose of confining the harmful swarming phase of the Red Locust and the African Migratory Locust, respectively, to certain relatively small areas in Africa which, on the evidence at present available, appear to be the only areas permanently liable to give rise to outbreaks. The outbreak areas for the Red Locust are the Rukwa valley of southern Tanganyika and the marshy depression known as the Mweru wa Ntipa in Northern Rhodesia, both of which are liable to be flooded annually by rivers carrying rain water into them but have no outlet for the water except by evaporation. The corresponding area for the African Migratory Locust is the great plain bordering the river Niger between Timbuktu and Segou, which is flooded and drained annually by the river. Each of these outbreak areas is subjected to continuous scouting and to monthly estimation of the locust populations in the various sectors of it. In this way bands of hoppers, incipient swarms of adults, concentrations likely to induce gregarious behaviour, and mere increases in population without marked concentration, are detected in time for appropriate action to be taken. Wherever suppression of the locusts is thought necessary, this is achieved by chemical means. It cannot yet be assumed that the work of these two international organizations will always prevent the development of plagues of the locusts that they aim to control, but it now seems almost certain that they will at least reduce very greatly the chances of it. Since either species, having once broken out from its outbreak area in the swarming phase, is liable to spread by alternate migration and multiplication over the greater part of southern Africa (though not entirely the same part in the two cases), the recognition and delimitation of the permanent outbreak centres for both are to be regarded as research achievements of outstanding value, for which assiduous and often monotonous reporting of locust occurrences for a long period of years was an essential basis.

Similar and even more extensive geographical research has been devoted to the Desert Locust, but with different and more complicated conclusions. At the time of the writing of this article, a plague of this species is raging from India and Pakistan in the east, through the Middle East and North Africa to West Africa, and southwards as far as Tanganyika. This vast

area of the earth's surface is recognized from past records as being the maximum invasion area of the Desert Locust, which, unlike the other two species, does not invade southern Africa. Despite the very careful and systematic plotting and analysis to which the accumulated information has been subjected, no geographically definite outbreak areas comparable to those of the Red and African Migratory Locusts have been revealed. On the contrary, it is now almost certain that no such area exists for the Desert Locust, and all that can be said is that many parts of the area occupied during plagues certainly are not permanently occupied by it and that the frequency of breeding during plagues is highest in certain parts of Arabia, the Somali peninsula and a few places elsewhere. Unfortunately, these particular areas are vast and their boundaries are vague and only arbitrarily definable; moreover, some of the areas in which breeding occurs most frequently in plague periods seem to be unsuitable for the non-swarming phase of the locust.

The Desert Locust therefore presents a particularly formidable problem, the solution of which still demands a long period of research in many different scientific directions. Fortunately, examination of past data has served not only to reveal that there are no definable outbreak areas, which is in itself an important though disappointing conclusion, but also to provide a clear picture of the annual and seasonal migrations of the swarming phase of this species throughout its invasion area, so that forecasting of the movements of swarms can be done with considerable reliability and the lines of further geographical and ecological research to be pursued can be logically decided. An essential step, following the recognition of some, at least, of the areas in which the available evidence suggests that the locust is always present, is the study of their vegetation and climate. Much progress towards this end has been made in several areas, and in general, the types of vegetation and the climate that constitute the habitat of the locust are well known. There is, however, no particular association of plant species that can be said to be characteristic of its ecology, and the degree of coverage and type of soil are more important than the composition of the vegetation. The principal characteristics of its permanent habitat are believed to be a semi-arid climate, sandy soil and ephemeral, quickly maturing vegetation, though there is considerable latitude in all these features. Despite the very evident desert association of this species, rainfall is essential for its breeding; it lays its eggs in the ground, as all locusts do, but only when the soil or sand is moist near the surface and to a depth of not less than two or three inches, and moisture is essential for the development and hatching of the eggs and also for the germination of seeds in the sand and the growth of seedlings of the annual plants on which the young hoppers principally feed.

The fact that the reproduction of this locust, an inhabitant of deserts, is entirely dependent on rainfall suggested that valuable information might result from a study of the relation between the occurrence and major movements of the locust, on the one hand, and the seasonal movement of moisture-laden air over the same regions, on the other. Meteorological stations are not numerous enough in these regions for this relation to be adequately ascertained, but the information available indicates very strongly that the

convergence of air currents causes not only the deposition of rain, but also the arrival of locusts in the same zone or locality, the effective direction of flight of the locusts being determined by the wind. Thus locusts, whether swarming or solitary, can arrive in a barren area almost simultaneously with the rain that they need in the soil for depositing their eggs, and when, after a few weeks, the eggs hatch, the resulting young hoppers find plenty of plant food in the ephemeral vegetation that springs up in the desert after rainfall. This conception of the inevitable arrival, in certain seasons, of locusts in localities where rain has fallen in otherwise arid areas has clarified our ideas of the importance of deserts as breeding places. It suggests that a desert region, considered as a whole, may be a permanent home of the Desert Locust, even though any one locality in it rarely contains any locusts. It also suggests that full knowledge of seasonal air movements over the whole of the region likely to be occupied by the locust, and especially of the zones in which opposing currents meet, would greatly enhance the accuracy of locust forecasting and might well serve to enable us to define far better than we can at present, the areas that are the most important as potential sources of locust swarms. With these ends in view, a study of the available relevant meteorological data for the whole area is about to be commenced.

A rather different meteorological problem is that of the influence of day-to-day changes in weather on the relatively local movements of adult locusts. This is clearly necessary in connection with the forecasting of swarm movements for control operations, especially when aircraft are being used to attack swarms that move daily. This problem also is receiving attention. A variation of it relates to the seasonal movement of adult locusts from one part of a breeding area to another. In the outbreak area of the African Migratory Locust on the Middle Niger, the population of adult non-swarming locusts in any one locality in the plains has been shown to be subject to abrupt increases and decreases which can be explained only on the basis of similarly sudden, though unobserved, migrations between the plains and the surrounding semi-arid country. Evidence of such an interchange of populations has been obtained in recent years by marking locusts in tens of thousands in particular localities and capturing some of them after periods of weeks or months elsewhere, but the weather conditions with which a sudden exodus of locusts is associated need, and are receiving, investigation. It should be noted that phenomena such as these seasonal migrations between important recognized breeding grounds and surrounding country suggest an inherent lack of rigid limitations in the general locust situation. This flexibility is further demonstrated by the fact that the Red Locust occurs in the outbreak area of the Migratory Locust, and *vice versa*, while there are other areas where both occur, probably permanently, but where neither swarms in years that can be said to be normal with regard to weather. We do not yet know whether or not areas other than the recognized outbreak areas of these two species are, in periods of exceptional weather, sufficiently altered to give rise to outbreaks. As research proceeds and experience accumulates, we shall build up an answer to this question; meanwhile, the organizations that exist for the suppression of any tendency of these two species to swarm are working unceasingly in the areas known to be dangerous, but with due awareness of the possibility of swarms arising elsewhere in special circumstances.

The conception of the whole locust situation as a dynamic and somewhat unstable system leads us to conclude that the differences between the Desert Locust and the Red and African Migratory Locusts with regard to outbreak areas are of degree only, even though very evident. The Desert Locust is essentially a nomad, living in regions where any tendency to limitation of movement to a particular, relatively small area would be fatal. The other two species are also nomadic, but in regions where permanent habitation is possible. The region occupied by the Desert Locust in plague periods, however, overlaps those occupied by the other two in corresponding periods, even though only slightly. The Red and African Migratory Locusts are mainly grass-eaters, while the Desert Locust eats a great variety of plants, and grass is unimportant in its natural diet, but in captivity, the latter thrives on a diet of grass only. The difference in natural diet is clearly associated with the difference in natural habitat, and cannot be said to be fundamental.

These three species share with one another, and with all other locusts, a capacity for living and behaving either solitarily or gregariously, according to circumstances. In this respect, any locust population is said to be in a particular phase at any particular time. The extreme phases, known as *solitaria* and *gregaria*, differ greatly, not only in behaviour but also in colour and relative dimensions of parts; all possible intermediate forms occur, but in any particular population all the locusts are usually in approximately the same phase. The two phases can be produced in the laboratory, though not in their most extreme form in all species. Hoppers that are *solitaria* in colouring on hatching become *gregaria* if reared in crowds and remain *solitaria* if reared in isolation, and locusts kept in crowds give rise to offspring which are *gregaria* in coloration. In the latter case, a few locusts in a cage constitute a crowd, their offspring being of the same colour as those of locusts kept crowded together in much larger numbers. Numerous experiments on these and other similar lines have thrown much light on the problem of phase and the factors that determine it. Much work has also been done in the laboratory on the activity and rate of maturation of locusts in relation to degree of crowding and on the effect they have on one another when in close proximity. In suitable conditions, particularly of temperature and humidity, hoppers can be induced to ' march ' together in cages in much the same way as they do in their natural environment, and having been induced to move in concert they cannot easily be caused to lose their gregariousness. The sexual maturation of both males and females is accelerated by the proximity of males that are already mature, and conversely, male maturation is retarded by the presence of very young males or females. There is thus ample manifestation of the importance of the interactions of locusts with one another in relation to the behaviour, density and size of a population as an entity.

The study of the behaviour of solitary and gregarious locusts in the field is being conducted simultaneously with laboratory research. In the case of the Desert Locust, field work with *solitaria* or non-swarming locusts has been impossible in recent years because all populations have been gregarious, but non-swarming populations of the Red and African Migratory Locusts have been available and have been investigated in the permanent

breeding grounds of these species. Attention has been focused on the small-scale movements of scattered locusts from one type of vegetation to another and on the factors that cause non-swarming locusts to congregate together and so lead to transformation to the more dangerous swarming phase. Amongst these factors, an unstable mosaic vegetation appears to be specially important.

Locusts differ from grasshoppers only in that, after a large local population has been built up by breeding in conditions that are favourable to them over a restricted area only, they form themselves into cohesive bands and swarms of individuals that display a high degree of uniformity of behaviour. We do not yet know what it is in the individual swarming locust that causes it to differ in behaviour from solitary individuals of its own kind, or why the cohesiveness of swarms and bands sometimes persists day after day and week after week and is extremely difficult to disrupt even by major disturbances. Research on these problems is going on continuously, however, in the field and in the laboratory, and some important results and conclusions have already been achieved. Investigation of the mechanism and physiology of locust flight, and especially of the rate of consumption of fat as fuel during flight, is indicating how long locusts individually can remain airborne, how far they can travel in known weather conditions, and how much time and food they need to restore their fat supply for further prolonged flight. Vertical photographing of swarms in flight and subsequent detailed analysis of the photographs are providing much information on the density, structure and cohesion of swarms, especially in relation to wind, and experiments that are being conducted at the same time are beginning to throw light on the sensory reactions of adult locusts to one another and also to their fellows in the mass. Similar work on the formation of hopper bands and on the behaviour and reactions of the hoppers themselves in the bands is proceeding concurrently.

All this research, and much more that is being conducted at the same time, has for its ultimate object the solution of the problem of the prevention of locust outbreaks. The Desert Locust, at the present time, is receiving more attention from research workers than any other locust species merely because the current plague is offering particularly good opportunities for studying the swarming phase, but the Anti-Locust Research Centre views the Desert Locust as only a part of an immense problem which can be claimed to have now reached a stage of partial but by no means adequate solution. It is necessary to recognize and allow for the very real differences that exist between the species with regard to natural environment and therefore the nature of control measures that can be usefully and economically applied; but it is even more important to recognize the inherent similarities between the species as it is only by discovering the fundamental reasons for the development of the tendency towards concerted behaviour in vast numbers that the problem as a whole can ever be solved by means other than chemical, or means that involve only very limited use of chemicals.

In the future, as in the past, the progress of research, the testing and utilization of results obtained, and the effective co-ordination of research items that lie in different scientific fields, will be directly or indirectly dependent on regular and efficient surveying and reporting of the locust

situation, both during and between plagues. This is the basic requirement on which the satisfactory development of locust-control policy and methods inevitably rests. Those who are asked to provide the basic information on the occurrence of locusts in their areas can be assured that the efforts that they make in their task of routine reporting are an essential contribution towards the solution of the locust problem.

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A Farm Institute in the Southern Sudan

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In backward areas there comes a time when, with primitive methods of agriculture being the general practice, junior government agricultural staff and skilled labourers drawn from the indigenous population are required to assist in research and development schemes. It is a difficult time and it is through this stage that the southern Sudan is at present passing. Some of the problems of agricultural education in this area and attempts to answer them are described below.

Situated in the south-west corner of the Anglo-Egyptian Sudan at an altitude of 2,300 ft. and in an area of shifting cultivation, the Yambio Agricultural Institute draws its students from among the many tribes in the southern provinces of Upper Nile, Bahr el Ghazal and Equatoria. It functions to provide the two lower levels of government staff:

(1) *Junior Agriculturists*—These are officials on Provident Fund contract who are capable of supervising simple schemes. Their starting rate of pay is £E.108 per annum. Trainees for this course, which lasts for three years, are recruited from the intermediate schools after eight years of education. The first year of their three years in the Institute is spent with the first year of the agricultural overseers' course (see below). This ensures that they experience the considerable amount of hard practical work of that year. Also it becomes possible to check their aptitude for agriculture before allowing them to proceed further. This is followed by their two year course.

(2) *Agricultural Overseers*—These are employees who work as skilled agricultural labourers and have a starting rate of pay of £E.40 per annum. Trainees for this course, which lasts two years, are recruited from the elementary schools after six years of general education.

In neither of the above cases has the trainee received any secondary education and thus the teaching of theory is clearly precluded. Further, since the capacity of entrants for learning has reached its limit, it is important that the technical education offered them is adjusted to their level. Entrants to Yambio Institute are capable only of extending their education and embracing technical subjects by spreading their knowledge sideways at the same level as that at which they failed to go further in their general education. It is important to recognize that those students of greater learning capacity who are capable of continuing their education upwards are usually accepted for further general education at a higher level in other institutions. In view of this, instruction is arranged with a view to preparing the trainee to meet the day-to-day demands of his agricultural officer, when he enters government service. That is to say, consideration must be given to exactly what will be his various duties and how best he can be trained in the Institute to carry them out efficiently later on.

Coming from an environment of shifting cultivation which offers no

Figure 1. Agricultural Overseer demonstrating citrus budding at Yambio. (Photo by courtesy of Public Relations Officer, Khartoum)

Figure 2. Students at Yambio receiving payment of bursaries. (Photo by courtesy of Public Relations Officer, Khartoum)

permanent home, where the cultivations are small irregular patches surrounded by a tangle of tall bush, and the need to be provident is of little concern, the childhood environment of trainees is invariably a definite handicap to them. Village life, in fact, has done little to instil that sense of responsibility required in a government servant. The Institute is organized to meet this need. It has been found on investigation that any responsibilities learned by the trainees from their parents are usually towards other living creatures, for example, younger brothers and sisters, and possibly sheep and goats. Generally a resigned attitude exists towards their crops, while responsibility towards the manufactured article is non-existent.

Designed to produce staff who will at once be at home in their work in the government and who will not require additional experience before proving of use, the courses are arranged so as to pass out trainees who have learned to accept responsibility. To effect this change from being schoolboys to being acceptable as government servants much time is spent on responsibility training.

Experience has shown that for such training to bear direct relation to the daily problems met in government service, clearly defined working sections, similar to those forming government extension and research programmes, have had to be established within the Institute. These are as follows:

(1) Cultivations.
(2) Nursery.
(3) Vegetable garden.
(4) Plantations.
(5) Experimental holdings.
(6) Dairy.
(7) Small livestock (chickens, turkeys, ducks, *etc*).
(8) Skilled maintenance (care and supervision of small machinery, pressure lamps, bicycles, *etc*).
(9) General maintenance (care and maintenance of roads, bridges, *etc*).
(10) Crafts (improved native crafts developed to local agricultural use).
(11) Services (water and firewood supplies, *etc*).

These form the basis of all instruction, the work being so arranged that all activities fall within their framework.

With the establishment of these sections the programme of work has fallen readily into place. It has also made possible the responsibility training mentioned previously as the trainees are used as institute staff, having to manage each section for a month at a time in their second year. In order to achieve this the following staff and programme have been found to be successful.

INSTRUCTIONAL STAFF

This comprises three senior staff all of whom should be qualified and experienced agriculturists. One of these is also the Principal of the Institute.

Eleven agricultural overseers (one for each section of the work) each with long experience in his particular occupation to demonstrate his own especial skill.

A permanent labour force with whom the trainee gains experience in the handling of labour.

INSTRUCTIONAL PROGRAMME

Instruction both in the classroom and in the new skills and techniques in the field and workshop, is confined to the first year. The teaching programme is allocated as follows:

First Year

Junior Agriculturists—(These have already had a provisional year as agricultural overseers.) Instructed by one of the senior staff agriculturists who is responsible for all their activities. The programme is arranged to fit the agricultural calendar, each section being dealt with separately. Instruction is simple. It has been found necessary to supplement it by an explanation in the form of notes, which have to be typewritten and handed to the trainee for him to study and absorb slowly as the course proceeds. To these notes he adds the appropriate drawings and sketches as instructed, drawing from living material wherever possible. On completing his first year, the trainee should have in his possession eleven files (one for each section of the work). These contain all the information necessary to manage any section of work, when his time comes to gain experience, in his second year.

Agricultural Overseers—Instructed by one of the senior staff agriculturists who is responsible for all their activities. Instruction for this group is kept outside, away from the classroom. The only exception to this is an extension of their agricultural vocabulary. This is designed to improve their ability to understand instructions. Following the agricultural calendar as closely as possible instruction is given section by section and is solely practical, imparting those skills and techniques necessary in any improved system of agriculture. Each trainee has his own cultivation in which he grows as wide a selection of crops as possible. By the end of his first year the trainee should be so skilled as to be able to act as the head labourer, over the permanent labourers in any section, during his second year.

Second Year

In their second year both levels of trainee act as student staff of the Institute, managing the Institute farm, under the direction of the third senior staff agriculturist. This member of the teaching staff is also the farm manager of the Institute. This arrangement appears as follows:

Senior Staff Agriculturist (*Farm Manager*)—Responsible for the eleven sections using:

(1) Second year junior agriculturists as staff, each in charge of a section for one month at a time. These are responsible for all records, paying of labour, a monthly diary, *etc.*

(2) Second year agricultural overseers working as head labourers in each section for one month at a time, each being responsible for:

(3) The permanent labourers of his section.

In this way it is possible to observe the trainee working in conditions where he is learning to accept the responsibility and authority given to him.

To supplement the foregoing programme instruction in simple drill with second year senior trainees taking part in giving commands is considered desirable.

To help in the transition from living in an organized institution to the ways of life found in out-stations, institutional feeding is avoided. The trainee after receiving his monthly bursary is entirely responsible for his own meals. In practice it is found that three or four will together employ a boy to cook for them. The value of the trainee knowing how to deal with his personal problems when he starts work is appreciated both by the trainee and by his senior officer.

Agricultural education at this level is possibly the most difficult to present. It brings the beginning of an awareness of the advantages of organized agriculture. Such awareness is made uncertain for the trainee, however, by his particular tribal superstitions and beliefs.

Eventually the demand for this type of trained person diminishes and with it comes a change in the Institute programme. With an absence of organized agriculture it has been found necessary to keep the agricultural programme divided into sections as the pieces of a jigsaw puzzle. At the time of such a change in demand, which would result from a change in overall policy, the experimental holdings should be developed and ready to receive the other ten sections which had been developed separately, and so make a complete working unit, that is, the nursery, dairy, plantations, *etc* must have been developed so as to be ready for incorporation in a suitable native holding.

When this happens the next educational stage will be set, *i.e.* the Farm School, and the Institute will be ready to begin instruction to the cultivator.

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Establishment of Parasites of Diatraea Saccharalis *F. in Dominica (British West Indies) and Guadeloupe (French West Indies)*

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D. saccharalis, the small moth borer of sugar cane, has been known in Dominica, B.W.I. for over 50 years, but since the sugar cane growing area of the island is small little attention has been paid to it.

During a visit to the island in November 1951 sugar cane was examined in several areas. At Goodwill Estate very little borer was present, though severe damage had been reported in previous years. At Grand Savannah a fairly large area had recently been planted with sugar cane, mostly B.37161, and both here and at Bagatelle, where there was a second fairly large area of cane, attack was severe, between 20 and 30 per cent of the joints of half-grown cane being attacked. Some *Diatraea* was also seen in a small plot of cane at Portsmouth Agricultural Station and in sorghum at Grand Bay.

Of 120 larvae examined none was parasitized, and it was felt worth while attempting the introduction of larval parasites of *D. saccharalis* as these were readily available at that time.

In general the rainfall in Dominica is heavy. At Bagatelle it averages about 120 in. per annum, but Grand Savannah is very much drier, averaging about 60 in. This appeared to be a good opportunity to try out all three well-known Tachinid larval parasites—*Lixophaga diatraeae* Tns., *Metagonistylum minense* Tns., and *Paratheresia claripalpis* Wulp. (from Trinidad). The former supposition that *Lixophaga* would only thrive in dry areas and *Metagonistylum* in wetter situations has recently undergone some modification in view of the fact that both occur commonly in dry and wet areas in Guadeloupe (Simmonds, 1953) and in view of the establishment of *Metagonistylum* in a very dry area in Venezuela (Box, 1953). Hence it was hoped to release both these species in Dominica. *Paratheresia claripalpis*, of which there appear to be a number of races in different parts of Central and South America, including Trinidad, has never been successfully and permanently introduced into a new area in spite of many attempts, *e.g.* Grenada, Barbados, Puerto Rico, U.S.A. Conditions in Dominica appeared to be very suitable for it and it was decided to try this species also.

Accordingly shipments of adult parasites, a good proportion of them females which had already mated, were sent from Trinidad for release at

various points in Dominica. The following were shipped between 28 November 1951 and 16 January 1952.

	Lixophaga	*Metagonistylum*	*Paratheresia*
No. of shipments	4	1	4
No. of individuals	327	100	691

Unfortunately all the *Metagonistylum* were dead on arrival, and as the other flies had been in transit for two days, with a change of aircraft in Barbados, they were not in first class condition on arrival. However, *Lixophaga* and *Paratheresia* were liberated at both Grand Savannah and Bagatelle by the Department of Agriculture, to give the parasites a chance in both a dry and a wet area.

In May 1954 F. D. Bennett of the Commonwealth Institute of Biological Control spent some time in Dominica studying several problems, and made a check on the results of the introductions of *Diatraea* parasites. Infestation by *Diatraea* was very much lower (about 5 per cent joint infestation) than at the time of my visit in November 1951.

However, small collections of *Diatraea* larvae were made. One sample of 11 larvae was made in June at Bagatelle; eight of these produced *Paratheresia* puparia, two *Lixophaga* puparia and the other larva died. A small collection made at Bagatelle in July was sent to Trinidad. Owing to mishandling by the airline this took 18 days in transit and only seven larvae arrived alive; four of these produced *Paratheresia*, two *Lixophaga* and one an adult *Diatraea*.

A further collection was made inland from Bagatelle in a patch of cane at Bellevue some three miles from the nearest parasite liberation point. Eighty-two *Diatraea* larvae were collected in a few days prior to 24 July Of these 48 produced *Paratheresia* puparia, seven *Diatraea* pupae, and 26 died. There were no *Lixophaga* but one larva produced a cocoon of *Agathis stigmaterus* Cress. (a new record for Dominica). Thus of the living material 87·5 per cent was parasitized, 85·7 per cent being by *Paratheresia*.

In November 1954 Mr. Bennett again visited Dominica and at Grand Savannah joint infestation was estimated to be less than 5 per cent. Both this and the earlier figure for 1954 compared very favourably with the degree of attack on the same area in November 1951. No parasitized larvae occurred in the few living larvae collected at Grand Savannah. Two assistants collecting at Bagatelle for two days obtained four *Diatraea* larvae and a pupa. Of the larvae two were parasitized by *Paratheresia*. In three days at Bellevue the two assistants collected 10 *Diatraea* larvae of which two were parasitized by *Paratheresia*, and one by *Agathis stigmaterus*. With these larvae were collected five *Diatraea* pupae and three *Paratheresia* puparia. Eight larvae, one *Diatraea* pupa, and three *Paratheresia* puparia comprised another two days' collection by one assistant. Of the larvae three died, two pupated and three produced *Paratheresia* puparia. Thus, from these small numbers it can be seen that *Paratheresia* is well established and parasitism is reasonably high, and damage to cane has certainly decreased considerably. It remains to be seen whether this decrease is permanent.

Lixophaga is certainly established at Grand Savannah and Bagatelle but does not seem to have spread as quickly as *Paratheresia*.

In Guadeloupe a puparium of *Paratheresia* was found at La Fenêtre section of Beauport in August 1954, some seven months after liberations had been made, and this species appears, therefore, to be at least temporarily established in an area with a rainfall of some 40 in. per annum. This seems to be rather dry for *Paratheresia* and it is hoped that it will become established in apparently more suitable areas of the island.

A further attempt was made to establish *Metagonistylum* in Dominica in November 1954, but with present parasites and diminution in attack by *Diatraea* in the cane this may be difficult.

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Tobacco Anthracnose—III: Experiments on Fungicidal Control of the Disease

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The failure of copper sprays to give effective protection against or to check anthracnose (*Colletotrichum tabacum* Böning) in Northern Rhodesia led to an intensive search for an efficient and readily available fungicide to replace copper. The present paper reports the results of experiments carried out in the laboratory, greenhouse and field towards this end. Fungicides were considered from the point of view of both soil disinfectants and protective sprays[2,3].

LABORATORY EXPERIMENTS

In laboratory tests, fungicidal materials were added to 30 cc melted cornmeal agar, thoroughly dissolved or suspended and poured into three petri dishes. The centres of each plate were subsequently inoculated with a small plug of *C. tabacum* culture. The ammonia and petrol vapour series consisted of inoculated petri dishes in which watch glasses of 0·880 ammonia or petrol were placed. The latter were included in the tests as ammonia has been used successfully for the control of damping-off organisms, and petrol vapour for the control of tobacco blue-mould (*Perenospora tabacina*). Results of these tests are presented in *Table 1*.

Table 1. Fungicidal Activity of Various Chemicals in Culture

Fungicide	*In medium* per cent	*Mean diam. colony after 9 days* mm
Potassium permanganate	0·1	56·6
Ammonia gas	—	0
Petrol vapour	—	76·0
3% methoxy ethyl mercuric chloride	0·25	0
7·7% mercury *p*-toluene sulphonilide	0·25	0
2·5% phenyl mercury acetate ..	0·25	0
4% calomel dust	0·25	17·3
75% Thiram	0·25	0
76% Ferbam	1·00	0
76% Ziram	1·00	0
65% Zineb	1·00	v. slight growth
Copper oxysulphate (45% Cu) ..	1·00	11·0
Colloidal sulphur (40% S)	1·00	23·3
Control, no fungicide	—	75·0

All the materials tested, except petrol vapour, gave some measure of control of the fungus. Only materials which inhibited growth entirely or permitted slight growth were selected for test in the greenhouse, primarily as soil disinfectants. In place of ammonia gas, a mixture of lime and

ammonium sulphate was used for soil treatment to generate ammonia in situ. Bordeaux mixture, 1/40 formalin, and Cheshunt compound were also included in greenhouse trials.

GREENHOUSE EXPERIMENTS

Greenhouse tests were carried out in asbestos-cement trays of 1 sq. ft. area filled to a depth of $2\frac{1}{2}$ in. with a loam soil. Sand/cornmeal inoculum of *C. tabacum* prepared as described previously[3] was added at the rate of 5 g/sq. ft. and worked into the soil surface. In inoculated but untreated trays, the pattern of infection obtained was the appearance of ' primary ' lesions on the lower leaves followed by the rapid development of ' secondary ' lesions[2]. Soil disinfection was aimed at the prevention of ' primary ' infection and thereby checking ' secondary ' spread. Spray treatments provide protection from air-borne inoculum arising either from ' primary ' infections or externally to the beds. Since so large an amount of inoculum as 5 g/sq. ft. invariably kills a large proportion of the seedlings notwithstanding the presence of soil disinfectants, results of all but the early trials are expressed as the number of seedlings surviving out of 500 seeds sown. Seed was sown by weight, it having been previously determined that 0·04 g of seed contains 494–506 (approx. 500) seeds. Fungicides were therefore tested under the most exacting conditions which would not normally be encountered in field practice.

Soil Disinfection Trials

In a preliminary series of tests fungicides were added to the soil in water suspension or solution at the rate of 100 cc/sq. ft. at the percentages indicated in *Table 1* with the exception of the ammonium sulphate and lime which were distributed dry and watered subsequently. Seed was sown on the day following soil treatment. Results of the preliminary experiments were expressed in terms of percentage of diseased seedlings in the trays three weeks after sowing and are given in *Table 2.*

Table 2. Fungicidal Activity of Various Chemicals Against C. tabacum *in Inoculated Soil*

Fungicide	*Diseased seedlings* per cent
1 g $(NH_4)_2SO_4$ + 2 g lime/sq. ft.	16·6
Methoxy ethyl mercuric chloride	20·0
Phenyl mercury acetate	3·6
Mercury *p*-toluene sulphonilide	0
Thiram	0
Ferbam	0
Ziram	0
Zineb	0
1/40 formalin	0
0·5% Cheshunt compound	8·6
4:4:50 Bordeaux mixture	13·3
Control—no treatment	16·2

In view of lack of agreement in some instances between greenhouse and laboratory tests, the above experiment was repeated. Precisely similar results were obtained on the second occasion. The unexpectedly high

percentage of infection with ammonium sulphate and lime and methoxy ethyl mercuric chloride is difficult to explain except that the reaction of these substances with the soil may have been such as to render the end products non-fungicidal.

The four thiocarbamates were selected for further trial both as soil disinfectants and protective sprays. Experiments with formalin were discontinued owing to the high cost of this material locally and the difficulty of application on a field scale. Mercury *p*-toluene sulphonilide was also omitted from further tests on the basis of cost.

Doran[1] reports that fungicides applied to the soil dry, mixed with fertilizer, are equally effective for disinfection as those applied in suspension or solution. In the case of tobacco seed beds which sometimes cover as much as an acre on any one farm, the application of fungicide to the soil in fertilizer recommends itself for simplicity and ease of distribution. The selected thiocarbamates were accordingly tested for efficiency and absence of phytotoxic effects mixed with fertilizer as compared with water suspensions.

Four trays for each fungicide under test were inoculated with *C. tabacum* sand/cornmeal culture. Fertilizer of composition 3:13:8 was applied to the aqueous suspension series of trays at the rate of 14 g/sq. ft. These trays were subsequently treated with fungicidal suspensions at 100 cc/sq. ft. and seed was sown. For the fertilizer cum fungicide series, fungicide and powdered fertilizer were mixed in the proportion 0·5 g to 14 g and distributed over 1 sq. ft. of soil surface followed by sowing of seed. Eight weeks later notes were taken on the amount of anthracnose infection and appearance of seedlings; these are presented in *Table 3*.

Table 3. Fungicides Applied to the Soil Mixed with Fertilizer Compared with Aqueous Suspensions

Fungicide (0·5 g/sq. ft.)	*Disease intensity & phytotoxic effects*	
	Suspension	*Fertilizer*
Thiram	Germination seriously impaired	
Ferbam	Germination good. Disease apparent on lower leaves.	Germination good. Disease on lower leaves but less than in suspension series.
Ziram	Germination seriously impaired	
Zineb	Germination erratic but no disease observed	
Controls	Total loss of seedlings	

The fungicides behaved similarly in fertilizer and aqueous suspension; further trials were confined to mixtures with fertilizer. At the dosages used in the trial set out in *Table 3*, the thiocarbamates were found to differ considerably from one another both as regards their efficiency as fungicides and in their phytotoxic effects. Ferbam did not give the same measure of control as in previous tests, while Thiram, Ziram and Zineb were in varying degrees phytotoxic. The latter three fungicides were further tested at different rates of application for efficiency and phytotoxicity. In this series

of experiments and thereafter, results are expressed as the number of seedlings surviving out of 500 seeds sown.

Table 4. Effect of Thiocarbamates at Different Rates (Survival, seedlings/500 seeds)

Fungicide	0·125 g/sq. ft.	0·25 g/sq. ft.	0·5 g/sq. ft.
Thiram	19	12	32
Ziram	10	27	72
Zineb	5	77	121
Control		10	

Obvious phytotoxic effects, taking the form of stunting and failure of root development, were noted at even the lower rates of Thiram and Ziram and probably accounted for the loss of a proportion of the seedlings. Zineb gave the highest survival rate without undue phytotoxic effects although at the highest rate there was a temporary check to germination for two or three days.

Protective Spraying Trials

Ziram, Ferbam and Zineb were compared with Bordeaux mixture for effectiveness in providing protection against and control of air-borne inoculum of *C. tabacum*. Trays were sown with 500 seeds, the seedlings being allowed to develop for six weeks. Trays were then inoculated by atomizing a spore suspension of *C. tabacum* over the seedlings. The day following inoculation, the thiocarbamates were sprayed over the inoculated seedlings at the rate of 0·08 g/100 cc water to the run-off stage. Bordeaux mixture was applied at 2:2:50 strength. Two trays were used for each material, two being left as controls. Spraying was continued twice weekly for three weeks. Results are recorded in *Table 5*.

Table 5. Control of Anthracnose with Fungicidal Sprays

Fungicide	*Survival seedlings/500 seeds* (mean)
Ziram	216
Ferbam	180
Zineb	174
Bordeaux	125
Control	8

Although fungicidally, Ziram proved the best of the thiocarbamates, it caused stunting and distortion of the foliage. Ferbam and Zineb were of the same order of effectiveness. Bordeaux mixture, while providing a fairly high degree of seedling survival, did not give the same protection as the organic fungicides. At the conclusion of the experiment, seedlings in the Bordeaux-treated trays were heavily spotted while the thiocarbamates gave almost complete freedom from infection.

By treating the seedlings with fungicides following inoculation some idea can be gained of both the control value of the fungicides, *i.e.* the ability to arrest infections already commenced, and also the protective value, *i.e.* the

ability to prevent infection by provision of a suitable fungicidal cover on the leaves. The survival figure provides an estimate of the control value, while the amount of ' secondary ' spotting developing later gives an indication of the protective value.

Since Zineb proved the most promising fungicide used both as a soil disinfectant (*Table 4*) and as a protective spray, further trials were confined to this material. In order to test the maximum dosage that could be applied to young seedlings without phytotoxic damage, trays of seedlings were sprayed with suspensions containing 0·2, 0·4, 0·8 and 1·6 g Zineb/100 cc water. 0·2 g is slightly in excess of 1½ lb./100 gal., the normally recommended dosage. Phytotoxic effects taking the form of stunting and yellowing were noted in the trays sprayed with the suspensions containing 0·8 and 1·6 g/100 cc. Seedlings will therefore stand twice the recommended dosage, *i.e.* 3 lb./100 gal. without obvious injury.

Combined Soil Disinfection and Protective Spraying

Where nursery sites are used in successive seasons, both soil treatment and protective spraying are indicated to secure control of anthracnose. This is clearly shown by the results presented in *Table 6*. Zineb was used to pre-treat infected soil and seed was sown immediately afterwards. Three weeks after sowing, spray treatments were commenced as outlined under the heading Protective Spraying Trials, and continued up to the sixth week.

Table 6. Soil Disinfection and Protective Spraying

Treatment with Zineb	*Survival seedlings/500 seeds*
Soil disinfection 0·5 g/sq. ft.	101
Spray 0·2 g/100 cc twice weekly	12
Soil disinfection + sprays	137
Control—no treatment	9

Spraying alone will not prevent infection on the undersides of the leaves from soil-born inoculum, and while soil treatment reduces the amount of inoculum, it does not eliminate it entirely. Thus in the series only soil-treated, a proportion of secondary spotting developed which caused some loss of seedlings, whereas in the soil-treated and sprayed series, there was no loss from ' secondary ' spotting.

FIELD TRIALS

In addition to a replicated experiment laid down where supervision was available, the co-operation of a number of farmers was obtained to treat a series of beds with Zineb.

The replicated trial comprised the following treatments: (*a*) soil disinfection, (*b*) spraying once weekly, (*c*) spraying twice weekly, (*d*) treatments (*a*) + (*b*), (*e*) treatments (*a*) + (*c*), (*f*) control, no treatment. Plots were 1 sq. yd. in area replicated four times. In all the field trials, soil disinfection was carried out by broadcasting a mixture of fertilizer and Zineb at the rate of 5 oz. Zineb/30 sq. yd. seed bed (approx. 0·5 g/sq. ft.). Spray treatments were commenced three weeks after sowing with Zineb at 3 oz. per

25 gal. water and 1 gal. of this mixture per 30 sq. yd. bed: this rate was doubled after the seedlings attained the size of a shilling.

In the replicated trial, only a small amount of infection developed on the control, sprayed and soil-treated plots; the disease was entirely absent from those plots receiving both soil and spray treatments. The extremely small amount of infection which developed was such as to make numerical comparisons between treatments impossible. However, beds only a short distance away, sprayed with 4:4:50 Bordeaux mixture developed severe anthracnose, thus indicating the superior protective value of Zineb.

Organized farm trials consisted of blocks of 10 seed beds, each bed of 30 sq. yd. area, which had had a previous history of anthracnose infection. The beds were pre-treated with Zineb in fertilizer and three weeks after sowing, spray treatments were commenced as indicated above. In two such trials, no disease appeared on the treated beds though neighbouring Bordeaux-treated beds were severely affected.

Finally, several growers used Zineb both as a protective spray and also to treat seed beds where the disease had broken out. All have reported excellent protection from, and control of the disease.

SUMMARY

(1) Fungicides for soil disinfection and protective spraying against tobacco anthracnose were selected progressively by submission to laboratory and greenhouse trials.

(2) The thiocarbamate fungicides, in particular Zineb, were superior to copper, mercury and sulphur compounds when used for soil disinfection. Thiocarbamates were also superior to Bordeaux mixture when used as sprays. Some phytotoxicity was noted with the thiocarbamates, especially with Thiram and Ziram.

(3) Good control and protection from infection was achieved in the field with Zineb used both as a soil disinfectant and protective spray.

ACKNOWLEDGEMENT

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A Rapid Method of Propagating Black Pepper

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PROPAGATION BY LEAF CUTTINGS

The literature on Black Pepper (*Piper nigrum* L.), mentions its propagation by seed and cuttings taken from the runners, but as far as the writer is aware, nowhere is propagation by leaf cuttings mentioned. In 1953, the writer, while investigating the possibilities of the commercial establishment of the crop in the island of Dominica, B.W.I., was faced with a shortage of planting material. Propagation by seed was possible, but laborious and uncertain, and propagation from runners, though easy, appeared to be wasteful of plant material at a time of high scarcity value.

A preliminary trial was therefore made with leaf cuttings of Black Pepper taken from vines several years old and growing in the shade of the Kola Nut tree (*Cola acuminata*). Some field observations were also made in the use of different supports on which the vines could climb. Cuttings were taken with the petiole and bud attached, and trials were made with β indole butyric acid with a wide range of concentrations. The standard cacao propagating bin was used with coir dust as the medium. All concentrations, with one exception, resulted in complete necrosis of the leaf tissues. The successful concentration appeared to be β indole butyric acid at 2 mg/ml. of 50 per cent alcohol, using the quick dip method. Rooting took place in 21 days with a rooting percentage of 75. The plants were hardened for seven days only and three months after potting were ready for the field.

This note is written away from the site of the work (the writer having been transferred), but observations indicated that age, position of leaf, buds, *etc* would appear to influence successful rooting. *Figure 1* shows the use of the whole leaf, with well developed roots, and *Figure 2* an older leaf with a less developed root system. It would not appear necessary to use half leaf cuttings, as in the case of cacao.

THE USE OF SUPPORTS AND SHADE

Pepper requires the use of supporting trees in order to climb. Some of these supports also provide shade for the plants, but it is doubtful if shade is essential. Several trees have been listed as forming valuable supports for the pepper vine. Some of those in more common use are: *Cola acuminata*, *Erythrina indica*, *Terminalia spp.*, *Pterocarpus marsupium*, *Mangifera indica*, *Tectona grandis*, *Grevillea robusta* and *Spondias monbin.*

In the present field study, a heavy ground shade of *Tephrosia candida* was established as well as supports of *Jatropha curcas*, *Gliricidia sepium*, *Erythrina spp.* and *Crescentia cujete* (Calabash). ' Dead ' supports of ordinary hardwood

Figure 1. Photo illustrates use of a young whole leaf of Black Pepper which has well developed roots at 21 days, grown in a medium of coir dust

Figure 2. Photo showing cutting of older leaf with a root system not as well developed as Figure 1

posts with cross pieces of bamboo were also established to serve as a trellis for ease of harvesting the crop.

Preliminary observations showed that the best growth occurred on live *Crescentia cujete* (Calabash), dead blocks of which are largely used in the West Indies for growing orchids. On the other hand, *Jatropha curcas* and *Erythrina spp.* were climbed upon with difficulty. The cause in these cases seems to be largely mechanical, since the bark of these two trees appears to be too smooth to facilitate establishment of the aerial climbing roots of the vine. In the case of *Gliricidia sepium*, its mechanical advantage would appear to be masked by the physiological effect of its shade which tends to be too dense, slows down growth of the vines, and requires constant lopping. The fern *Gleichenia* as a dead post is used with success by some practical growers of the vine.

SUMMARY

(1) A rapid and successful method of propagating Black Pepper by the use of leaf cuttings is described.

(2) Trials with supports to facilitate climbing of the vine indicate *Crescentia cujete* as being the most suitable.

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The Kola of Nigeria and the Cameroons

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AN INTRODUCTION TO KOLA

' Parmi les produits végétaux dont l'antique et mystérieux sol africain nous promet une conquête et une assimilation complète, il n'en est peut-être pas de plus intéressant et de plus précieux que celui qui, sous les noms divers de Kola, Gourou, Ombéné, *etc*—est consommé dans toute l'étendue de l'Afrique tropicale et équatoriale. '

To the French professor Heckel[21] there seemed no vegetable product of Africa which surpassed kola in its interest and worth, and, although in the succeeding 70 years the African soil has been induced to yield other and more valuable products, we may still agree that none more interesting than kola has yet been produced.

Kola occupies a unique place in the life of West Africa. Not only is it a comestible of everyday use and the sustainer and comforter of the weary traveller and the toiling labourer, but it has also its particular uses in the social life and religious customs of the people. Amongst the Mohammedans, especially, is it valued most highly. A tradition from Sokoto (with a bold disregard for the geographical distribution of the tree) says that the Prophet was glad to rest in its shade, and it was his pleasure to give presents of the seed to his friends. In the remote past the trade in kola fixed the course of caravan routes and in these present days the timetable of the Nigerian Railway is so shaped as to include regular trains for carriage of this product. Kola influences the lives of many who leave their homes to buy or to sell it in distant markets.

The precious seed has accompanied the West African on his travels and, in the days of the slave-trade, its cultivation extended to tropical South and Central America and to the West Indies. It has also spread eastwards to Mauritius, Ceylon, and Malaya. Records from Kew[31] show that for a few years after 1880 it was propagated and distributed thence to botanic gardens in every part of the Empire where its cultivation was thought likely to succeed.

Yet, despite its importance to the African and its widened distribution into other tropical countries, this plant and its product are little known to the western world. It may well be doubted if there is any plant-product so greatly valued about which so little has been written. The lack of information in English is especially marked.

The most authoritative work on the subject ' Les Kolatiers et les Noix de Kola ' was written by the French botanist Auguste Chevalier and his collaborator Emile Perrot[1] and was published in 1911. In this work are detailed at length a history of kola as known to the western world, an account

of the species yielding edible seeds, and a description of their cultivation, trade, and uses. A later German work by SPRECHER VON BERNEGG[2] published in 1934 provides an admirable concise account of the botany of kola (based on Chevalier's work), its cultivation, and yield. In Dutch there is a short paper by BONTEKOE[7] describing the tree and its cultivation.

There is no comprehensive work on kola in English and, although frequent references to it are to be found in colonial reports and agricultural textbooks, many are misleading as well as incomplete. Earlier accounts, such as that of SCHLOTTERBECK[50] in America and an abstract in English of the work by HECKEL and SCHLAGDENHAUFFEN[22], are confusing through imperfect recognition of the species involved, and this confusion has persisted into such later works as the textbooks of NICHOLLS and HOLLAND[40] published in 1929 and FAULKNER and MACKIE[17] in 1933. Some paragraphs by BURKILL[9] in 1935 give a clear account of the identity of the kola of commerce and its history.

The cultivation of the crop has not been described in any fullness in English though there are numerous incomplete accounts of its growing and fruiting, of which those by HUNTER[25] in the Gold Coast and MATHIEU[35] in Malaya may be cited as examples. A description of the uses and properties of kolanuts was given by DANIELL[15] in 1865, and a more recent and valuable account by DALZIEL[14]. Finally, VOELCKER[56] has published the results of original work on the inheritance of colour in the cotyledons of kola, a subject to be discussed more fully in a later section.

It is the purpose of this paper to describe the edible species of *Cola* met in Nigeria and the Cameroons, to give an account of their cultivation and productivity, and in so doing to draw attention to this genus of plants which plays so important a part in the life of West Africa and has had such casual recognition from British botanists.

The Genus Cola

Cola is a Tropical African genus of the family Sterculiaceae of which over 40 species are listed in the *Flora of West Tropical Africa* as revised by KEAY[27]. They are evergreen trees of the forest, mostly small or moderate in size though a few rise to some height.

Cola was separated from the genus *Sterculia* in 1832 by SCHOTT and ENDLICHER[51] on the basis of flower and fruit characters. While both genera are without petals and have a white or coloured corolla-like perianth, *Cola* has anthers regularly arranged in a double or single ring round the base of the ovary in the hermaphrodite flowers or on a synandrium in the male flowers, in contrast to the irregular arrangement of anthers found in Sterculia. In *Cola* the seed is normally without endosperm, the fruit dehiscent.

Most of the species of *Cola* have seeds which are hard and inedible. Those with seeds which are good to eat, for which Chevalier and Perrot designated the sub-genus *Eucola*, are comparatively few and probably referable to six species. In distinguishing between them, certain characters of the leaf, fruit, and seed are of special value.

The leaves of the species of *Cola* with which we are concerned are simple, entire, and narrowed or rounded towards the base. The arrangement of the leaves on the stem is alternate in some species and verticillate in whorls

of three or four in others. This is a convenient character for separating the species, but it is perhaps worth noting that the verticilly is not absolute since, in trees in which the majority of shoots are whorled, it is sometimes possible to find shoots with alternate leaves.

The flowers of *Cola* are of two kinds, the male flowers in which only the rudiments of a gynoecium appear, and the hermaphrodite in which the gynoecium consists of a several-chambered ovary bearing conspicuous stigmas. In the species discussed here, the chambers of the ovary and the stigmas are usually five, but the number is not invariable. As it develops after fertilization, the ovary divides forming separate fruiting carpels or follicles, five in number or fewer by abortion. These are sessile at the end of a short fruiting stem from which they radiate in star-shaped fashion. As the fruit increases in weight, the stem hangs vertically and the follicles are borne horizontally or ascending in recurved fashion according to their kind.

A feature of interest in *Cola* is the occurrence of polycotyledony in some species. The seed of the edible species is ovoid or ellipsoid, or angular by compression, varying in size up to 5 cm long and 3 cm across. The bulk of the seed consists of the cotyledons to which is attached the minute embryo. In the chief kola of commerce the cotyledons are two in number and the seed readily splits into two halves. In other species there are three or four cotyledons, sometimes as many as six, and the seed splits into a corresponding number of pieces when broken.

Recognition of the Species of Cola

The so-called ' nuts ' of kola used so widely in West Africa from remote times, were well known to early European voyagers to that territory. A reference to ' goro ' as a bitter fruit-like chestnut derived from a tall tree, was made by the Spanish Moor, Leo Africanus[28] in 1556 after a visit to the western Sudan. Descriptions of kolanuts written in 1593 by a Portuguese traveller to the Congo, Edouardo Lopez, who saw seed of four cotyledons, and a few years later by a Dutch physician, Roelsius, who described nuts splitting into two, are quoted by Chevalier and Perrot. The trees from which these seeds came were not known to these travellers and two more centuries passed before they were properly recognized.

In 1805 part of Palisot de Beauvois' ' Flore d'Oware et de Benin en Afrique '[42] was published, the result of a stay by him during 1786 and 1787 in that area, now the Delta and Benin Provinces of Nigeria. Here he became familiar with the tree giving the kind of kola grown in those parts which he named *Sterculia acuminata*. Specimens which he collected, now in l'Herbier Delessert at Geneva and the Herbarium of the British Museum, are incomplete being without fruit and seed, and he depicted a seed with two cotyledons as being produced on this tree. It was therefore assumed that Palisot de Beauvois had found the tree producing the popular kola of trade, his name (as amended by Schott and Endlicher to *Cola acuminata*) became widely adopted and still persists here and there as applying to the common kolanut.

In 1805 also there appeared the second volume of l'Abbé Ventenat's ' Jardin de la Malmaison '[55] with a short description of *Sterculia nitida* sent him by Michaux from a botanic garden in Mauritius. Ventenat's specimen

from this source in l'Herbier Delessert is incomplete without fruit or seed. When Schott and Endlicher separated the genus *Cola* from *Sterculia* in 1832, this became *Cola nitida* (Vent.) Schott and Endl., but it remained incompletely described.

Meanwhile there had appeared in 1827 a book by SCHUMACHER[52] containing Thonning's description of *Sterculia verticillata*, a tree bearing its leaves in whorls and having edible seeds used as kolanuts.

In 1883 HECKEL and SCHLAGDENHAUFFEN[22] wrote an account of kola and its properties in which they suggested that it might profitably be used in the pharmacopoeia of western countries. There followed a period of great activity by German botanists in Tropical Africa in the course of which much interest was taken in kola and many efforts made to separate the different kinds.

A valuable contribution at this time was Schumann's Sterculiaceae Africanae[53] in which he described the species of *Cola* then known. He pointed out that the popular kola of commerce with two cotyledons was not *C. acuminata* but a distinct species for which he proposed the new name *Cola vera*. He also described as *C. anomala* a species with verticillate leaves collected in the high Cameroons.

German botanists in West Africa continued to find new forms of kola which they had difficulty in fitting into Schumann's list and they proceeded to make new species of them, sometimes, it would seem, from incomplete material and with inadequate cause. Amongst the species separated were *C. sublobata* and *C. astrophora* named by WARBURG[59] and *C. supfiana* by BUSSE[11].

By now the identity of the edible kolas was in a state of indescribable confusion and it is very much to the credit of the French botanist Auguste Chevalier that, in his work published in 1911 in collaboration with Emile Perrot[1], he was able to bring order out of chaos and to give a clear account of the various species with adequate descriptions.

Chevalier concluded that Palisot de Beauvois was mistaken in attaching a seed with two cotyledons to the herbarium specimens he collected from Benin and Warri. In Chevalier's opinion his specimens, and therefore the name *C. acuminata*, clearly belong to the kola native of that district which has more than two cotyledons.

He considered also that the popular kola with two cotyledons described by Schumann as *C. vera* is the species described earlier by Ventenat and must therefore be called *C. nitida*.

Some inadequately known species such as *C. sublobata*, *C. astrophora*, and *C. supfiana* he discarded, regarding these as forms of established species, and at the same time he excluded *C. anomala*, a decision with which we shall later have cause to disagree.

While we may not follow Chevalier wholeheartedly in all his conclusions, we cannot fail to appreciate the solid foundation he has laid for further work on edible kolas. Although his classification has been accepted slowly, particularly in this country, it has nowhere been disputed and, indeed, little or no subsequent work on the identity of the edible kolas has been published.

Five species are included in Chevalier's sub-genus Eucola: *C. acuminata*, *C. nitida*, *C. ballayi*, *C. verticillata*, and the imperfectly known *C. sphaerocarpa*.

Two of these, *C. ballayi* and *C. sphaerocarpa*, have not been recognized in Nigeria or that part of the Cameroons with which we are concerned, and have no further mention in this paper.

THE EDIBLE SPECIES OF *COLA* IN NIGERIA AND THE BRITISH CAMEROONS

A study of the kola grown in the forest zone of southern Nigeria and in the neighbouring Cameroons under British Trusteeship has revealed that several species and forms of *Cola* are being used. The Yoruba farmer of south-western Nigeria recognizes at least four kinds of kolanut to which he gives vernacular names:

(1) Abata (*C. acuminata*), the kola favoured by the Yorubas.

(2) Gbanja (*C. nitida*), the main kola of commerce of which three forms have been distinguished.

(3) Owé (*C. verticillata*) regarded as of inferior quality.

(4) Abidun (probably *C. verticillata*), used medicinally.

To these must be added a species grown in the high Cameroons:

(5) The Bamenda kola (*C. anomala*).

It is proposed to describe the occurrence of these various kinds and the characters by which they may be distinguished. Herbarium specimens have been deposited at the Royal Botanic Gardens, Kew, and I am greatly indebted to R. W. J. Keay and J. P. M. Brenan who examined this collection and determined the species.

1. Abata kola: *C. acuminata* (Pal. de Beauv.) Schott and Endl.

This is a slender tree up to 40 ft. in height, more usually 20 to 30 ft. The trunk commonly branches near the base and the branches are many, frequently dividing, slender and crooked, markedly ascending.

The bark of old trees is rather rough and corky, grey in colour, splitting into squares. On the larger branches the bark is smooth, but corky warts and an olivaceous colour are frequent and are distinctive characters of this species when present.

The foliage is sparse and confined to the tips of branches. The leaves are very dark green, rather fleshy, the lateral veins not prominent. In shape they are elliptic or slightly obovate, rounded at the base and with a long acumen as much as 1 in. in length. The leaf is not flat but is curled, keeled at the mid-rib and twisted at the tip. Measurement of a large number of leaves from different sources gave the following mean figures (maxima in parentheses): lamina length 6·4 in. (11·5): breadth at widest 2·2 in. (4·4): petiole length 1·6 in. (4·0).

The inflorescence has several to many flowers which are not arranged in whorls. The flowers are rotate or sub-campanulate, the hermaphrodite one barely 1 in. across, the male flower smaller. In both cases the perianth segments are joined for nearly half their length and are white with a small red coloration at the base of the segment inside, the colour being most marked along the veins. The perianth is glabrous inside or with scattered stellate hairs. The anthers are borne on a short but distinct column.

The fruit consists of up to five follicles borne at right-angles to the stalk or slightly downwards (not bent upwards as in *C. nitida*). The follicles

are sessile, straight or slightly curved with a prominent straight point or tip, the whole being up to 8 in. long, $2\frac{1}{2}$ in. across, the surface rough or corky, russet or olive-brown. The seeds are up to 14 in each follicle arranged in two rows, ovoid or angular through compression, up to 1·6 in. long and 1 in. wide, covered with a white skin which is thin but rather fleshy. Within the skin the seed is commonly pink or red, occasionally white: cotyledons three to five or even six, seed tender and succulent, bitter in taste.

This species is indigenous in the forest zone of southern Nigeria, but most of the trees which occur have been planted by man. It is extensively grown in Yoruba country, particularly in the provinces of Oyo, Ondo, and Ijebu, to a less extent in Ibadan Province and Benin. Near Ilesha there are villages which depend for their prosperity on the growing of this tree and near the village of Iwara the writer walked for the best part of a mile through a continuous planting. This kola is planted in the shade of taller forest trees and usually at a close spacing of 12 or 15 ft. It is typically planted also at the side of bush-paths leading out from a village, forming avenues along the main paths.

This species of *Cola* flowers abundantly in the dry season from December to February, to a less extent in August and September, and most fruits are harvested from April to June. (In this respect *C. acuminata* differs markedly from *C. nitida*.) The fruits are broken in the field and the seeds still in their white skin are placed in baskets and carried to the village. The seeds are soaked in water for a night to soften the skin which is then easily removed. The cleaned kola is kept in the houses in baskets lined with large green leaves of various wild plants and these are renewed from time to time to keep the nuts fresh until required for use.

This is the kolanut used ceremonially and socially by the Yoruba people of western Nigeria and valued by them above all others. It is not appreciated by the people of northern Nigeria and the Sudan who are the chief buyers of kola. The trade in abata kola is therefore a very local one and distribution is only to the large towns and to those drier parts of Yoruba country in which the tree will not flourish.

In Yorubaland a supply of abata is normally kept in the house and the offering of kola forms part of the greeting to an honoured guest. The older the kola the more highly it is regarded, and white and pink nuts are preferred and are kept for favoured guests.

The gift of kola, and particularly the splitting and sharing of a kolanut between two or more people, signifies a special bond of friendship. Similarly, kola may be exchanged when a business deal or contract between parties is arranged. It is invariably used in ceremonies relating to betrothal and marriage. Johnson[29], describing the customs of the Yorubas, refers to the importance of the betrothal ceremony which is attended by all the members of both families who are free to come. The young man to be betrothed is expected to provide the company with a supply of large kolanuts which are split and handed round so that all present may have a piece and so indicate that they are parties to the alliance.

At the wedding celebrations, kolanuts are supplied by the bride's family and here we see evidence of a popular association of kola with fertility. Besides kola, there are passed round alligator pepper (*Aframomum melegueta*),

the so-called ' bitter kola ' (*Garcinia kola*), and honey, signifying the fertility and productivity, the prosperity and contentment, desired for the union.

Besides being a symbol of friendship between men, kola is commonly used as an offering to obtain the favour of the pagan gods. MURRAY[39] mentions its use for this purpose at a pagan festival in 1948. He describes its further use in divination to learn the mind or intent of the god. The polycotyledonous seeds of this species of *Cola* split into bits with three sides, some of which are convex, others concave. A handful of these bits is tossed by the priest so that they fall to the ground, and the distribution of concave and convex is used to tell whether the deity is pleased or angry, whether or not the barren will have children, or the sick be restored to health.

Greatly as the trees of abata kola are prized now, they appear to have been valued even more highly in the past. JOHNSON[29] in describing the earlier history of the town of Ibadan records that most of the kola trees in the town were the property of the Chief, and that he often offered human sacrifices amongst the trees to ensure their fruitfulness.

2. Gbanja or Goro: *C. nitida* (Vent.) Schott and Endl.

This is a more robust tree attaining to 60 ft. in height, but more commonly from 30 to 40 ft. The trunk is usually unbranched for several feet, and old trees may have narrow buttresses extending up the trunk for less than 3 ft. The main branches are thick and rather few, ascending or spreading but not dividing frequently. The bark of the trunk and lower limbs is smooth with fine longitudinal cracks.

The foliage is dense and not confined to the tips of the branches. The leaves have long petioles with prominent pulvina, and are rather variable in size and shape, commonly obovate, sometimes rather long, with the base of the lamina usually cuneate, the tip abruptly acuminate. The leaf is flat except that the tip is sometimes slightly bent, the lateral veins are very obvious, making furrows in the upper surface of the leaf. Measurement of 200 leaves from various sources gave the following mean dimensions and maxima (in parentheses): lamina length 7·5 in. (12·8): breadth at widest 2·8 in. (5·0): petiole length 1·9 in. (6·1).

The inflorescence is non-verticillate, the flowers rotate or slightly cupped. Hermaphrodite flowers are commonly $1\frac{1}{4}$ in. long but as much as 2 in. across: male flowers smaller, about $\frac{3}{4}$ in. In both cases the perianth segments are divided for at least two-thirds of their length and in the typical form of this species are white or cream coloured with a small dark-red marking at the base of the segment inside, extending a short distance up the three veins. The perianth is glabrous inside or with only a few scattered stellate hairs. There is little or no column to the androecium which is almost sessile at the base of the perianth and is more or less red in colour.

The fruit is composed of up to five follicles borne on a short hanging stem, the follicles usually in a recurved position. The follicle is roughly ovoid but curved, the more convex dorsal side with a pronounced keel which is produced into a short terminal curved beak. The follicle is considerably shorter and more curved than that of *C. acuminata*, not exceeding 5 in. in length and about $2\frac{1}{2}$ in. in width. When nearly mature it is shining green in colour, though sometimes mealy-white when young, and the

surface is often rugose or tuberculate. The fruiting carpel contains up to 10 seeds in two rows. The seed, which is covered with a thin tough membranous white skin, has two cotyledons (occasionally three), sometimes white, more commonly pink or red. The seeds are variable in size, often 2 in. long, ellipsoid or angular by compression.

The occurrence of ' races culturales ' within this species is noted by Chevalier and Perrot who go so far as to describe these as four sub-species, *alba*, *rubra*, *mixta* and *pallida*. The chief differences between these lie in the colour and size of the seeds, but *alba* is distinguished also by absence of red coloration in the flower. It has not been found possible to divide the species *C. nitida*, as represented in Nigeria, into these four sub-species. Indeed, from Chevalier's description it appears to the writer that the distinctions made are too slight to justify the formation of sub-species. Nevertheless, whatever rank one cares to give them, the existence of races or forms within this species is undeniable. Two distinctive kinds of gbanja kola, differing in certain characters from the common form already described, have been noted in Nigeria on Government farms and in farmers' plantings near Ibadan, one of thich corresponds closely with Chevalier's *C. alba*. Until the differences between these and the more common form have been proved to be greater, it appears preferable to regard them merely as forms of *C. nitida* and they are here referred to as ' white-flowered ' and ' red-flowered gbanja '.

2a. White-flowered gbanja (probably Chevalier's *C. nitida* sub-sp. *alba*)

In this form the flowers are completely white or cream-white and lack the red star-shaped marking at the base of the perianth and the red coloration of the androecium which are features of the common form. There are also small differences in leaf characters which may enable this tree to be distinguished in absence of flowers. In general, the leaves of the white-flowered kola are shorter, more rounded, and have more numerous and closer lateral veins. It is thought that this tree grows from white seeds and that pollination amongst trees of this form leads to production of white seed only. On the other hand, all white seed does not give rise to this form and in three plantings of white-seeded kola on Moor Plantation, the Government farm near Ibadan, some of the resulting trees are of the white-flowered form and others of the common form with red-eyed flowers. The white-flowered kola came in one instance in a consignment of seed from Sierra Leone, in another instance from a planting near Lagos whose previous history is not known.

2b. Red-flowered gbanja

Another kind of kola which at first sight looks strikingly different from the common form has large flowers whose perianth is completely of a deep maroon colour inside, while the outside is of a white or cream-white colour. The habit of the tree and shape of leaf are normal. The only fruits seen on this tree were immature, but they resembled young fruits of *C. nitida* in their shape and in their knobbly, rugose exterior. The seeds appeared to have two cotyledons but were so little developed that this could not be determined with accuracy. However, several farmers whom I questioned

about this kola insisted that it was ' gbanja ', that is kola with two cotyledons. This dark-flowered kola is not uncommon on farms near Ibadan. It seemed plentiful near the village of Offa-Igbo in Ibadan Province where the characteristic blossoms were seen on several trees in September 1953.

C. nitida of SCHOTT and ENDLICHER[51], the *C. vera* of SCHUMANN[54], is the true kola of popular trade. This species is a native of the forest zones of Sierra Leone, the Ivory Coast, and the Gold Coast, all of which lie to the west of Nigeria. It has for long been cultivated in these countries and more recently in Nigeria itself. The seed, gbanja or goro-nut, is consumed all over West Africa and particularly in the Sudan, the region largely peopled by Mohammedans which extends almost the width of the continent south of the Sahara.

Chevalier and Perrot have mapped the routes followed from remote times by caravans carrying kola from the forest zone to the great northern markets such as Timbuktu, Sokoto, and Kano, and the extent of this trade has been the subject of comment by early travellers. A century ago BARTH[4] described the steady stream of kola he saw moving by head-load and on donkeys into the country we now know as northern Nigeria. To a missionary stationed in Upper Volta I am indebted for a description of the extensive trade which continues today on one of these old routes, kola from Ashanti being conveyed first by motor-lorry and then by donkey-load to the frontier of the French Sudan at Leo, whence it travels onwards to the north and east.

Modern methods of transport have to some extent superseded the old. Within a short time of the completion of the railway linking Lagos and Kano in 1912, large quantities of kola were being shipped from Sierra Leone and the Gold Coast to Lagos and were travelling thence by rail to the north. These shipments through Lagos, however, soon met competition from a rising local production in the face of which they declined. Doubtless the local farmers saw this great traffic in imported kola in the port of Lagos and on the railway to the north and sought to have their share in it. As a result the last 40 years have seen the planting of this species of *Cola* on an extensive scale from Lagos up the course of the railway, so long as this passes through suitable land, and in the areas on each side from which good roads give ready access to the railway.

C. nitida now occupies large tracts of land in the district near Lagos known as the Colony, and in the adjoining provinces of Ijebu, Abeokuta, Ibadan, and Ondo. The railway carries from this area between 50,000 and 60,000 tons of kolanuts annually to the markets of northern Nigeria, and additional quantities which cannot at present be fairly estimated are consumed in the south or find their way north by other routes.

A feature of most villages in this part of Yoruba country is a group of huts outside the village, occupied by Hausas from the north who are engaged in buying kola from the Yoruba farmers, packing it, and sending it to their home-country.

In the main, the growing of gbanja kola is confined to the lowland rain-forest zone as defined by KEAY[71] in his account of Nigerian Vegetation, and ends quite sharply where the forest gives way to savanna. It is of interest, therefore, to find a small area of *C. nitida* far beyond in the drier climate to the north where its growth, according to ELLIOTT[31], is made possible by the

occurrence of wet land with a high water-table. This is the celebrated kola of Labozhi in Bida Emirate, considered to be superior in quality to kola from all other sources. The trees were formerly the property of the Emir and the precious fruits were carefully guarded, with death as the penalty for anyone found stealing or in possession of the nuts from this plot. They are now less strictly preserved and seed from this source was used in 1935 for experimental planting near Ibadan. The resulting trees provide the seed which is offered to farmers by the Department of Agriculture for planting. The seeds are large and are greatly sought after, but in botanical characters this Labozhi kola has not been observed to differ in any material respect from the typical form of *C. nitida* which has been described.

The chewing of the goro-nut is a widespread and almost universal habit in northern Nigeria which has been likened in some respects to the tea drinking or cigarette smoking of western countries. Even in the south it is widely practised, and the clerk will commonly have two or three nuts in his desk to support the tedious hours of mental effort, while the lorry-driver will not fail to have a supply in his cap to sustain him through the rigours of his journey. Like *C. acuminata* amongst the Yorubas, *C. nitida* in the north has its social and ceremonial uses, for example, as a fitting gift to the welcome guest, or to the parents at a betrothal, but it would seem to have a much greater usage than *C. acuminata* as a comfort and solace of daily life.

Thanks to its content of caffeine and theobromine, gbanja kola is a sustainer and stimulant, and it enables the user to travel long distances without fatigue and gives him endurance to go on though short of food and water. A letter written by the British Consul at Bahia, Brazil in 1890, quoted in the Kew Bulletin[31], records the great powers of strength and endurance shown by West African negroes who were users of kola, in carrying loads in that place, and he suggests that this powerful commodity might profitably be brought to the notice of Her Majesty's War Office.

Kola temporarily dispels sleep and in Chevalier and Perrot's work it is recorded by one of the authors that, by taking kola after his midday meal, he was not only able to do without the siesta commonly taken in the tropics, but kept awake with ease and found intellectual activity stimulated and thoughts sharpened.

To one who is not a regular user, the taste is bitter and hardly attractive though the after-taste is not unpleasant. In places where the water has a bad taste it can be rendered apparently sweet and pleasant by the eating of a kolanut before drinking.

Finally, this kola induces a feeling of well-being and contentment in the user to such an extent that Sprecher von Bernegg[2] recommends every manager of a plantation in the tropics to plant an area of kola that he may have happy and contented workers.

3. The kola known in Yoruba as owé; *C. verticillata* (Thonn.) Stapf ex A. Chev.

Though attaining a greater size, this species is similar in habit to *C. nitida* from which it can be distinguished by the leaf arrangement, the colour of the flowers, and the form of fruit and seed.

The tree grows up to 75 ft. in height but more commonly is 35 to 50 ft.

The bark of the trunk and main branches is brown with longitudinal cracks, the branches are few, ascending or horizontal. The leaves are verticillate, usually in whorls of four, occasionally three, obovate or elliptic, rather gradually acuminate, with a flat lamina not twisted at the tip. The lateral veins are very prominent on the under side of the leaf and can distinctly be seen to curve near the margin and join the next lateral vein. There is a distinct network of fine veins.

The inflorescence is pilose, with crowded flowers arranged in small whorls. Flowers are rotate or slightly cup-shaped, the segments dissected rather more than halfway, with numerous stellate hairs within and without. The perianth has a mealy-white appearance outside, but inside is cream coloured or yellowish with a carmine tinge covering the lower half of the segments. The androecium has a short column so that the anthers are clearly borne above the perianth cup.

The fruiting carpels are ovoid, borne nearly at right-angles to the stem, nearly straight, short and stout, in length 5 to 6 in., in breadth 3 in. They are not rugose but are even and rounded, with a smooth and shining, or slightly roughened, surface. A pronounced furrow on the dorsal surface is bounded by ridges forming a slight keel produced at the tip into a short beak. The seeds are six to eight in number, in two rows, each seed enclosed in a very thick white fleshy skin. The cotyledons are three or four (occasionally two or five), and are pink or red. The seed is rather tough, chewy, and lacking in flavour.

In farmers' plots of *C. nitida* near Ibadan there are sometimes a few trees of this kind. The seed finds a market, but it is considered inferior to gbanja and fetches a lower price. I was unable to find a farmer who would say why he took the trouble to grow this inferior kind, but it appeared to me that it commonly fruits between May and July, that is three or four months earlier than the bulk of the gbanja, and perhaps sells at a time of year when the better kola is scarce and expensive.

This tree conforms to Chevalier's description of *C. verticillata* (Thonn.) Stapf, the kola known as ' hanurua ' by the Hausas, and probably the ' Wasserkola ' described by GRUNER[20]. It is sometimes called by the Yorubas ' obi oloye ' which is said to mean ' slimy kola ', but this name is used also for the variety next to be described.

C. verticillata has a wide range in West Africa. It is presumed to be native of southern Nigeria having been collected in forest apart from habitation. Cultivated trees are found scattered through the south and have been recorded from Northern Nigeria in Nupe territory. Although planted on a small scale over so wide an area, this species cannot be regarded as of much economic importance.

4. The kola known as abidun; probably a form of *C. verticillata*

The trees of this kind which were seen amongst *C. nitida* attracted attention by their greater size and stouter growth, the arrangement of leaves in whorls, and the different shape of their fruit.

The height is up to 75 ft. and the trunk stout and unbranched for 10 or 12 ft. with a chestnut-brown bark. The lower branches are large, horizontal or ascending, and commonly bear many upright succulent shoots or chupons.

On some of these, the leaves are borne in whorls of four, but in others the arrangement is alternate as in *C. nitida* and *C. acuminata*. The leaves on these chupons are borne at right-angles to the stem, on long petioles. Some are very large, with lamina up to 15 in. long and 5 in. broad, and petiole 5 in. long. On fan-branches the leaves are smaller, often in whorls of four. The lateral veins are few and widely spaced, not pronounced on the upper surface but very prominent below.

The inflorescence is pilose, with flowers sometimes, but not invariably, in small whorls. The flowers are rotate and white in colour with a red marking in the centre, this coloration being larger than is normal in *C. nitida* and the perianth segments more hairy inside.

The follicles are large and broad, up to 7 in. long and $3\frac{1}{2}$ in. across. They are almost straight and are not rugose, and little, if at all, knobbly, though they may bulge through pressure of the large seeds. There is a thick keel on the more convex side, produced into a short beak. The colour is variable, from a shining green to a russet-brown, and one tree was seen with a young fruit which was silvery-white, rather scaly and rough to the touch. Seeds are about six to eight in a follicle, each seed with a very thick mucilaginous white skin as much as 1/3 in. in thickness. This skin and the white lining of the carpel when exposed to air rapidly turn to a bright yellow colour. The seeds are large, up to 2 in. across without the skin, and are pink or red with two, three or four (occasionally five) cotyledons. This variety is so bitter as to be considered unfit for eating. It is, however, used medicinally, being believed to promote fertility. Ripe fruits were seen in October and December.

This description is mainly based on four trees in a cacao farm at Agodi near Ibadan, but other and very similar trees were seen elsewhere in the district. According to Dalziel[14] the name ' abidun ' is properly ' obi-edun ' or monkey-kola, a name apparently given to any type of kolanut which is not worth eating and is presumably only fit to be left to the monkeys. Chevalier and Perrot, however, give ' abidan ' as a native name for *C. verticillata*.

The tree described here approaches most nearly to *C. verticillata* with which it agrees in characters of fruit and seed. It is at variance in so frequently producing shoots with alternate leaves, and flowers not invariably arranged in whorls in the inflorescence. To users of kola it is a well-recognized kind, to be avoided for normal purposes on account of its bitter taste and poor texture. Until this kola is better known, it seems possible to point to no obvious and constant botanical character separating it from *C. verticillata*, and it is here assumed to be a form of this species.

5. The kola of Bamenda, *C. anomala* K. Schumann

This tree may reach a greater size than any other of the edible kolas here described. The largest tree seen was estimated to be 90 ft. in height with a trunk more than 6 ft. in diameter. Most specimens were about half this height. The trunk is typically unbranched for some distance, the branches relatively few, ascending or horizontal. The bark of the trunk is rather smooth, cracking in oblong pieces, while that of the branches is smooth with longitudal cracks.

The foliage is dense, the leaves being spaced along the small branches and not confined to the tips. The leaves are verticillate in whorls of three, occasionally four, often borne at rather an acute angle with the stem. The leaves are flat, stiff and leathery, of a dull green colour and less shining than in the other species which have been described. They are also less in size, the mean dimensions of a large number of leaves and their maxima being: lamina length 5·9 in. (11·8): breadth at widest 2·3 in. (4·5): petiole length 1·3 in. (3·3). In shape they are obovate, gradually acuminate with an unbent tip, and are not curved or twisted. The base of the lamina is rounded or gradually narrowed. Lateral veins are very prominent and projecting on the under side of the leaf. They tend to be rather straight and at an acute angle to the mid-rib.

The inflorescence is few-flowered with flowers rather crowded and in whorls. The surface is covered with a tawny felt of hairs. The perianth is campanulate, opening much less than in the other species described here, the segments divided for less than half their length, yellow in colour without the pronounced red marking of the other species, and very hairy inside and out. The fruiting carpels are green or olive with a smooth skin when mature, but rugose and knobbly, strongly keeled at the dorsal suture, the keel extended to form a point. Several seeds, each with a thin tough testa, and three to six cotyledons, pink or red in colour.

This species has been seen only in the highlands of the Cameroons, in Bamenda Province and the adjoining territory towards Dschang, administered by France, at heights of 3,000–7,000 ft. This country is formed mainly of rolling grassy hills amongst which the position of villages can be seen afar off by the occurrence of dark masses of trees. These are mostly this species of kola, planted between the huts and giving shade and protection to the village. The tree has a most characteristic rounded billowy outline rendering it easily recognized.

All specimens of this tree seen by the writer were evidently planted by man and there seems no record of its occurrence in the wild state. It is the only edible *Cola* seen growing in Bamenda Province during several visits and is perhaps the only one which will grow at altitudes above 3,000 ft. The seeds from this tree were the only kolanuts seen in the market at Banso in November 1952. There were large supplies in the market and I was told that the nuts are chiefly bought by Hausas for conveyance to their country to the north. The kola is packed in wide-meshed baskets lined with leaves and is carried by head-load over mountain paths to Yola in Adamawa Province. The price in Banso market at that time was 5*s*. for 100 good nuts. The local name is ' bi ' but this may merely be a word for kola and may not refer specifically to this variety.

As in other species, flowering and fruiting continue during several months. Trees were seen in full blossom in June and the main season for the ripe fruit is probably about September and October. Judging by the great numbers of trees grown, the trade in this kola is both large and profitable.

C. anomala was first described from this district of the Cameroons by Schumann[53] in 1901. Chevalier, who did not see this tree, was not satisfied from the description that it differed significantly from *C. verticillata* and he accordingly treated it as a synonym of this species. The trees at Bamenda

differ from *C. verticillata* in form of leaf, in shape and colour of flower, and in fruit characters. From herbarium material sent to Kew, Keay and Brenan consider the Bamenda kola to be that described by Schumann and to be a distinct species.

It may be concluded then from these observations that at least four species of *Cola* are cultivated in Nigeria and the Cameroons for their edible seeds. Of these by far the most important in trade, *C. nitida*, is not native but has apparently been introduced in recent times. The wild source of *C. anomala* is not known but the cultivation of this species is of much importance in the highland district in which it is grown. Of the two species known to be native of Nigeria, *C. acuminata* is of some economic importance in the country of the Yoruba people, while *C. verticillata* is of minor value and is regarded as of inferior quality wherever it grows.

In places where these species grow together, hybridization may be expected to occur. The crossing of *C. acuminata* with *C. nitida* has been effected without difficulty by controlled pollination, and the resulting progeny have been grown to maturity. The hybrid plants may resemble one parent or the other or have characters intermediate between those of the parents. Hybridization of the other species of *Cola* here described has not been attempted.

The following key is suggested for separating these four species:

Leaves with alternate arrangement (though a false verticil may terminate the shoot): flowers non-verticillate.

Fruit straight or only slightly curved, not rugose or tuberculate, russet, rough to the touch; seeds with more than two cotyledons; leaves long-acuminate, curved and twisted. *C. acuminata.*

Fruit curved, with prominent keel extended to form a curved beak, rugose or tuberculate, green, smooth to the touch; seeds with two cotyledons; leaves rather abruptly acuminate, flat, nerves prominent. *C. nitida.*

Leaves mainly verticillate in whorls of three or four: flowers usually verticillate.

Fruit rugose or tuberculate, beaked: seeds with thin tough testa and more than two cotyledons; leaves mostly in whorls of three, gradually acuminate, lateral veins prominent, rather close and straight. *C. anomala.*

Fruit rounded non-tuberculate; seeds with a very thick fleshy testa, cotyledons two to six; leaves in whorls of four or three (occasionally alternate), rather abruptly and shortly acuminate, lateral veins distinctly curved. *C. verticillata.*

THE CULTIVATION OF *COLA NITIDA* IN NIGERIA

C. nitida is grown extensively in western Nigeria within the forest zone from the coast inland for nearly 100 miles and from the boundary with Dahomey on the west for about 200 miles eastwards towards the Niger. In the southern part of this area, on the light soils bordering the coast in which cacao will not long survive, kola is grown as a sole crop in wide-

spread plantings. Farther inland, on the better soils where cacao is an important crop, kola trees are often planted through the cacao. Thus, within a block of more than 6,000 cacao trees comprising nearly 10 acres at Agodi near Ibadan, planted by farmers and later placed in the care of the Department of Agriculture, there are 145 trees of *C. nitida* and a few trees also of *C. acuminata* and *C. verticillata.*

The area in which the kola is mainly grown is within 6° and 7° north of the equator. The climate is both hot and humid, but with well-marked wet and dry seasons. Towards the south (as, for instance, at Agege) rainfall may occur over eight-and-a-half months, the dry season of three-and-a-half months being broken by an occasional shower, and annual rainfall reaching perhaps 70 in. Farther inland, at Ibadan, the dry season is more marked, extending for four-and-a-half months with few showers of any value, while most of the annual rainfall of about 48 in. falls in seven-and-a-half months. Whereas cacao will only grow under these conditions in soils with good moisture-retaining capacity, kola will flourish in both light and heavy soils so long as they have good depth. Nevertheless, it responds markedly to a well-drained, fertile soil containing much humus and in such conditions will produce the most vigorous growth and earliest fruiting, as shown by BUCHER[8] in the Cameroons.

The native farmer, in preparing land for planting *C. nitida*, clears the ground completely by cutting and burning all trees and bush-growth. This treatment, it may be noted, is quite different from that followed in the growing of *C. acuminata* which is invariably planted in the shade of taller trees. The cleared earth is then commonly scraped into small mounds or 'hills' on which the farmer plants food-crops, maize, yams, or cassava. Kola seed is planted between the hills at suitable spacing, generally about 20 ft. apart, sometimes as much as 27 ft. These temporary food-plants often provide the only shade given to the young kola and when it has grown beyond them it is expected to continue without shade of other trees. Sometimes the clearing of the original tree-growth was not thoroughly done and two or three survive to shade the planting. But no systematic planting to provide top-shade is done.

Chevalier and Perrot record that, in parts of French Guinea where *C. nitida* is native, it is held to be most inauspicious to plant a seed of kola since the sower will assuredly die as soon as the seedling comes into flower. This belief has not accompanied *C. nitida* into Nigeria and the farmer here will plant his seed in the ground without foreboding and so far as is known without ill after-effect. The seed germinates under favourable circumstances in from seven to twelve weeks, though individual seeds may take much longer. During this time the germinating seed is vulnerable to attack by rodents and to drought, and loss may readily occur.

The early growth of the kola plant is slow and in normal conditions the tree is only 6 to 10 ft. in height after four years. The only cultivation attempted during this time is an occasional weeding given in tilling the interplanted food-crops. This inter-cropping is gradually given up as the kola increases in size and shades the ground. Flowering may occur about the fifth year, but it is not usually until the seventh that any fruit is seen and this is scanty. By the twelfth or fifteenth year a fair crop should be obtained

and the tree is considered to be in full production from the age of 20 years. Trees are long-lived and may well continue bearing until 70 or 100 years old.

Except on the occasions of harvesting, the trees receive little or no attention. It is, however, the farmer's custom now and again to slash the trunk of his kola trees with a cutlass. This is done just before the season of main flowering and the farmer believes it will induce the trees to bear more heavily. Many kola trees in Western Nigeria have wounded bark resulting from this practice.

At the start of the harvest period any undergrowth beneath the trees is cut so that all fruits falling to the ground can be seen. The careful farmer cuts the fruit from the tree before the follicles split open. The approach of maturity can be told by a change in colour from deep-green to a paler tint. To reach the fruit a long pole with a curved knife-blade attached to the tip is provided. Armed with this, a lad is sent up the tree and he scrambles amongst the branches cutting all the fruit he can see approaching ripeness. This should be repeated monthly during the fruiting season from September to January, and a few fruits may also be found in June and July. Greatest production is usually from October to December.

The harvested fruits are heaped on the ground at a convenient place under the trees and the follicles are split open. The seeds are removed and, still in their white testas, are placed in baskets and carried to the village. Their subsequent treatment includes three processes which may be carried out in slightly different ways, the removal of the testa, the ' sweating ' of the nuts, and their packing for storage.

In order to facilitate removal of the testa, it is rotted either by soaking the nuts in water or by heaping them into large baskets where they are left for about five days. The nuts are then rinsed in water and the softened fragments of testa wiped off.

The cleaned nuts are transferred to baskets, often of enormous size and without lining, and kept here for three or four days with frequent stirring. This is the process known as sweating and, although its purpose is not altogether clear, the effect seems to be a gentle reduction in water-content of the seed.

The seed may then be stored to await a favourable market, wrapped in green leaves and deposited in the ground or in a cool corner of a hut. Periodically the nuts are examined and fresh wrapping leaves applied. The leaves used are of various species but some Marantaceous plants are preferred including *Marantochloa* and *Thaumatococcus*, whose large leaves show resistance to rotting. The keeping-quality of the nuts depends greatly on the care with which the harvesting, cleaning, and sweating have been done. Under the best conditions the seed may be stored for many months without decline in quality.

More often the kola is bought without delay by the Hausa buyer. His first task is to inspect the nuts one by one, setting aside any showing insect damage, and then to grade them by colour and by size. Each lot is packed in a container sometimes known as a bly, a cigar-shaped package with an outer coat of sacking bound by native rope, and an inner coat of large green leaves which protect the nuts and preserve them from desiccation. The building of this bly round the nuts is done with much skill and speed by Hausa labourers. A belief quoted by Sprecher von Bernegg adds that

besides being adroit the packers must be honest men of sound character if the kolanuts passing through their fingers are to keep well. The closed bly is despatched without delay on its way to the distant markets by lorry or by rail.

There seem several respects in which the farmer might improve his practice in the growing of kola. The loss which is liable to occur when seed is planted in the open ground may be avoided by germinating the seed under protection. For plantings of the Department of Agriculture, the kola seedlings are raised in nurseries, each seed being sown in soil in a basket woven from strips of mid-rib of the oil-palm. When the seedling has produced a few leaves and favourable rains occur, planting-out is done in the field, the whole basket being sunk in the ground to avoid disturbance of the roots. This method costs more in material and labour than sowing directly in the field, but where valuable seed is being used the additional care is justified.

Seed may also be started in the soil of nursery-beds, but this method has proved less satisfactory. A deep taproot soon grows and this is likely to be damaged in transplanting unless the seedling is moved at an early age. Chevalier and Perrot describe a way of germinating the seed before planting which is practised by farmers in French Guinea. The seed is arranged in a heap in a cool place, such as the corner of a hut, and is watered from time to time. After some weeks the cotyledons separate, the radicle begins to grow out, and at this stage the seed is planted in the field.

In Nigeria little or no care seems to be exercised by the farmer in the selection of seed for planting. Yet, as will be shown later, there is very marked variation in the productivity of individual trees so that the use of planting material from high-yielding trees may be expected to effect great improvement in yields. One farmer only was met, and he was a grower of *C. acuminata*, who pointed out several trees in his farm which were most productive and from which he was careful to take the seed for his new plantings.

Propagation by cuttings is not a standard practice, but it can be done with fair success. In work at Ibadan, the tips of branches in which the wood was just beginning to harden were cut and were placed, after dipping in a rooting hormone, in a mixture of sand and rotted oil-palm fibre in a closed bin as used for cacao propagation. Rooting took longer than in the case of cacao but occurred eventually in a good proportion of cuttings. Similar success has been recorded by Pyke[47]. More knowledge is needed of the performance of kola grown from such cuttings of fan-branches before the method is more widely used. In the case of cacao, cuttings of this kind give a low-branching, bushy plant and it is possible that in kola the normal tree-habit may be impaired.

In our imperfect knowledge of the requirements of *C. nitida*, it is hardly possible to say with certitude what amount of shading should be given to the tree at different stages. For soil conservation it would seem desirable that, until the kola is able completely to shade the ground with its foliage, the shade of other trees should be provided. Once the kola has attained good size and has formed a complete canopy, it appears to thrive in Nigeria without the shading of taller trees. Kola, however, is easily damaged by

high winds and, during a tornado accompanying a tropical thunderstorm, large limbs may be torn from the trees. It is probable that the presence of taller shade trees would protect the kola to some extent and that even in mature life some overhead shade is thus desirable.

In recent plantings made by the Department of Agriculture the plot to be used has not been clean-felled, but selective clearing has been done, scattered trees providing light shade, such as *Albizzia zygia* and *A. sassa*, being left. Chevalier and Perrot recommend a similar practice, involving elimination of trees with dense foliage or with powerful root-systems and the sparing of useful trees which will not compete with kola. If shade is to be planted, WARBURG[59] recommends species of *Erythrina*, *Inga*, and *Albizzia*. Sprecher von Bernegg gives a scheme for planting kola using permanent shade of such species, and closer temporary shade provided by bananas and papaws (*Carica papaya*).

The extent to which shade is used must depend in part on whether or not other crop-plants are grown amongst the kola. The Nigerian farmer's practice of clearing the ground before planting kola is probably related with his intention of planting food-crops for several years while the kola seedlings are growing. This is to be reckoned as harmful to the kola to the extent that the stored fertility of the surface soil is depleted, but it does ensure that the kola is tended and kept free from weeds and it provides the farmer with some sort of living from the land while the kola is unproductive.

The possibility of growing permanent crops with kola is worth bearing in mind. Chevalier and Perrot favour cacao as the most suitable crop to grow beside kola, with perhaps oil-palm as a third crop. They also suggest Liberian coffee as an alternative to cacao. Experience in Nigeria indicates that kola and cacao are too competitive to be grown together with complete success and that the cacao is likely to yield poorly near the kola trees. Robusta coffee between rows of kola has grown and yielded well. High yields of coffee have been obtained in kola up to 18 years of age and, though with increasing density of the shade the coffee may be expected to decline at a later age, the supplementary revenues derived from the coffee in the earlier years may be of importance.

Any account of kola cultivation would remain incomplete if it failed to mention the pest which is so destructive to the nuts and is accordingly dreaded by farmer and trader—the kola weevil *Balanogastris kolae* (Desbr.) Faust, of the family Curculionidae. The presence of the pest is speedily recognized when the nuts are split by the occurrence of holes and tunnels in the tissue, while in the unbroken nut it is often possible to detect holes at the surface and extruded frass. The weevil was first described in 1895 by DESBROCHERS DES LOGES[16] and an account of its life history was given at the same time by PEREZ[43].

The insect spends the greater part of its life in the seed. The egg is laid in a small cavity in the surface made by the female, and the larva on hatching eats its way into the cotyledons which became riddled with its tunnels. When full-grown the whitish grub has a length of $\frac{1}{4}$ in. and it then pupates in a chamber near the surface of the seed. The adult weevil which emerges is about 1/6 in. long and is dark in colour. The adults soon mate and produce a new generation so that the pest increases rapidly in stored kolanuts.

Damage from this pest is widespread and is sometimes very heavy indeed, the weevilled nuts being considered unfit for any purpose.

The chief measures taken by the kola trader to reduce spread of the pest are the frequent inspection of his produce, the removal of any nuts seen to be infested, and sometimes the application to the stored nuts of ' medicines ' such as ground capsicums or chopped lemon-grass (*Cymbobogon citratus*).

Infestation commonly starts in the field and, even despite careful inspection, early damage may be overlooked and the pest find its way into the stored kola. Observations suggest that the insect fails to penetrate sound fruits in the field but enters seeds which are exposed through ripeness of the fruit or damage to the fruit walls. An effective means of control, therefore, is the regular and thorough harvesting of fruit before it reaches the point of splitting and, in the plantings under the author's control where this was done, the loss caused by this insect became of little importance.

Golding[18], in listing the pests recorded in Nigerian kola, refers to a Longicorn beetle, probably a species of *Phosphorus*, as an important pest. The larva of this beetle tunnels in the branches of the tree and may cause their destruction. During studies of the controlled pollination of kola made by the writer, heavy loss of the young fruits was traced to a Lepidopterous insect whose larvae bored into the developing carpels and destroyed them. Further investigation may show this pest to be widespread and a cause of serious loss of fruit.

The diseases of the kola tree have received no attention, but the absence of records suggests that there is no obvious disease of a destructive nature. Trees of *C. nitida* growing amongst cacao infected with swollen shoot have been carefully examined for signs of virus disease, but no evidence of infection has been seen. In transmission experiments with the cacao viruses, Posnette, Robertson and Todd[45] failed to infect *C. nitida*.

THE PRODUCTIVITY OF *COLA NITIDA*

The yields to be expected from *C. nitida*, as published by various authors, have been condensed in a table in the work by Sprecher von Bernegg[2] and show a mean production of nuts per tree ranging from 400 to 12,000 per annum. In referring to similar figures Chevalier and Perrot point out that yields of kola are often greatly exaggerated. In their reckoning, a tree producing 750 seeds in a year is doing as well as can be expected under the best conditions, the majority of trees will give half of this figure, and some trees little or nothing.

Actual yield figures at Kumasi on the Gold Coast, as quoted by Hunter[26], show that the trees in a 10 acre planting gave a mean yield of 143, 184, and 189 nuts in their twelfth, thirteenth, and fourteenth years after planting. These figures, however, cannot be accepted as representing full production, which is not normally reached until about the twentieth year.

In a series of reports from Agege Government Farm in Nigeria, Burr[10], Waters[60], and Poynter[46] have given yield figures for seven acres of kola during six years. The mean yield of 527 lb. of good nuts per acre approximates to a mean figure of 189 nuts per tree at a normal spacing of 60 trees to the acre.

Asked what he expects his trees to produce, the Nigerian farmer will give a high figure, perhaps 1,000 nuts, being doubtless carried away by the

occasional performance of an exceptional tree and forgetting the many trees which bear few fruits. The actual yield records on Departmental farms, on the other hand, may give too low an impression for, where the harvest period continues over many months, complete supervision of harvesting is hardly possible and theft is known to have occurred in some of the plots. The following are typical yield records at different ages.

Table I. Yield of Kola Expressed as Mean Number of Nuts Harvested per Tree in Different Age-groups per annum

Plot No. and acreage	*Mean ann. yield per tree (No. of nuts)*			
	Age-group			
	6–10 yrs.	11–15 yrs.	16–20 yrs.	over 20 yrs.
Ina: White Labozhi: 3 acres	11	35	91	
Moor Plantation D6: 2½ acres	5	59	87	
Moor Plantation Y5: 2½ acres (in poor state) ..			95	
Agege plot AA: 4 acres ..				210
Agege plot AB: 2 acres ..				210

These figures suggest that the trees are slow in coming into production and that from 200 to 250 nuts can be taken as a conservative estimate of mean annual yield of a mature tree of Nigerian kola.

Variable Yield of Individual Trees

A striking feature of the kola of western Nigeria, and one which has also been recognized elsewhere in West Africa, is the great difference in the productivity of individual trees in the one plantation. While one tree is bearing heavily, the next may be barren or producing but few fruits. This shyness of bearing is well known to the farmer and his customary measure to overcome it, by slashing the tree-trunk with his cutlass, has been mentioned earlier.

HUNTER[26], in analysing the yields of 150 trees at Kumasi on the Gold Coast, showed that most (79 per cent) yielded from 0 to 300 nuts in the year but that a few produced many more, and the highest nearly 1,100 nuts.

The following figures show the variability in yield typical of farmers' kola in Nigeria. They represent the yields of individual trees recorded in a plot of mature kola at Agege, originally planted and cultivated by a farmer, but now included within the Government farm. Regular monthly harvesting was done over a period of four years. It might be expected that a tree giving an exceptionally high yield one year would produce little the next (though study of the yield figures does not, in fact, bear this out, but rather suggests that a good tree is consistent in its high yield). However, to minimize any hidden effect of this kind there might be, the individual tree yields given are the mean annual yield of the tree over the period of four years.

Further analysis of these figures shows that 79 per cent of the trees had a mean annual yield between 0 and 300 nuts. The remaining 21 per cent of the trees produced 72 per cent of the total yield of the plot.

Table 2. Classification of 246 Kola Trees According to Mean Annual Yield, Agege Observation Plot AA, 1950/51–1953/54

Yield-class (Mean. No. of nuts per annum)	*No. of trees in class*
0	46
1— 100	85
101— 200	35
201— 300	26
301— 400	12
401— 500	11
501— 600	9
601— 800	7
801—1000	5
1001—1200	3
1201—1400	4
1401—2000	2
over 2000	1
Total	246

While the average yield of all trees in the plot was 210 nuts per annum, the 10 best trees averaged 1,415 nuts and the best tree 2,209 nuts per annum.

Variation in Seed Size

Trees differ in the size of seeds they produce as well as in their number. The seeds from any one tree vary in size and weight, and, indeed, in the normal follicle the seeds are unequal in size. Nevertheless, some trees consistently bear larger seeds than do others. In the period of four years the plot described above yielded 206,172 nuts with a total fresh weight, after removal of the testa, of 7,441 lb., a mean value of 27·7 nuts per lb. Individual trees varied widely from the mean, the nuts of one tree during the four seasons averaging 16·9 per lb. while trees with over 40 nuts per lb. were not uncommon. Seed size is obviously a character to be taken into consideration in assessing the value of a particular kola tree.

There was noted an apparent tendency for the many seeds of the high-bearing trees to be smaller than the fewer seeds on low-yielding trees. In each class, however, a wide range of seed weight occurred, and significant correlation between the number of seeds borne by the tree and the mean number per pound was not established.

The Selection of High-Yielding Trees

A study of individual tree records in several farms has shown high-yielding trees to be scattered about the plot, often with low-yielding neighbours. This distribution suggests that their superiority cannot be entirely attributed to their occupying especially favourable sites, but must in some degree depend upon a particular quality of the trees themselves. This can, however, only be proved by their vegetative propagation and inclusion in a critical field trial, a time-consuming task which has yet to be undertaken.

If we may assume what seems so probable, that high productivity is an inherent quality of certain trees, it follows that very great increases in yields of commercial kola are possible by a relatively simple process of selection.

From yield records of individual trees maintained over a period of four years or more, the trees producing many and large nuts can be spotted. By vegetative propagation these can be multiplied and planted to form a collection of superior high-yielding trees, which can be used as a source of seed for distribution to farmers. This is roughly the scheme started by the writer in Nigeria, the kola trees in observation plots at the Government Farm, Agege, providing the population from which outstanding trees have been selected on the basis of seed size as well as number of seeds produced.

While the variability in yield may be thus overcome by empirical methods, we are still left in ignorance of its cause. Records from Nigerian farms, and similar figures from the Gold Coast, have shown 79 per cent of the trees to be giving fewer than 300 seeds a year, the product of less than 25 fruits per tree brought to maturity. This is a poor achievement for any tree of the size of kola and one is led to enquire why so few fruits are ripened. Are there perhaps few fertile flowers opened ? Or, if plenty of flowers are borne, do they escape fertilization through the absence of pollinating insects or through some incompatibility ? Are many young fruits set and then lost before they come to maturity ? What is different about the few trees in the farm which consistently give yields far above the average ? Such questions as these prompted the studies on productivity which are described here and, although no ready answer was found, their account may nevertheless prove of interest.

The Flowering of C. nitida

In kola the flowers are produced on the young shoots, and flowering therefore follows the increases in growth made by the tree. A tree which, through unfavourable conditions, is not making active growth will produce few or no flowers or fruit.

Growth of the trees during the year is marked by a rhythmic alternation of periods of active growth or flushes and of intervals of dormancy, and is similar in many respects to the growth of the tea-bush as described by Bond[63] and cacao as shown by Greenwood and Posnette[67]. In kola the flush assumes the form of a more or less vigorous growth of new shoots which extend rapidly to a length of from 5 to 10 in. producing about six or eight new leaves. These quickly expand until they are fully grown and of a fresh green colour. Then follows a period of dormancy lasting for several weeks during which growth is halted and the new leaves slowly harden off and change to the normal dark-green colour and leathery texture of the mature leaf. Later still, usually four or five months after the flush, there is commonly produced an inflorescence, sometimes two or three, near the base of the newly-hardened shoot or towards the top of the previous growth.

Observations made in 1953 showed in that year there was a complete flush in April, in which nearly all trees and all branches of the tree took part, soon after the start of the rainy season. Partial flushes followed at intervals of about 10 or 12 weeks, but there was less uniformity about them, one tree flushing before another, or a flush of new growth appearing on a few branches and not on the rest of the tree.

Flowering followed a similar but later course, with a profusion of flowers on most trees in July and August and sporadic bursts of flowers thereafter.

Flowering ceased in December with the onset of severe dry weather, but in some years a few blossoms were found in May and June before the main flowering.

The flowers of *C. nitida* are of two kinds as described by MASTERS[34] for *C. acuminata*. The smaller male flowers have a short column on which is borne a ring of 10 two-lobed anthers, of which the anther-lobes are divergent and inserted one above the other. The gynoecium is vestigial. In the larger hermaphrodite flower the anthers are subsessile in a ring surrounding the base of an ovate stellate-pilose ovary, usually five-celled, bearing five styles, which are subulate, sometimes flattened, and reflexed.

The anthers in the hermaphrodite flower are complete and contain pollen which was proved to be viable by successful germination in sugar solution. Nevertheless, amongst the many hermaphrodite flowers examined none was seen in which the anther-lobes were split and the pollen exposed. Even when the flower had matured to the point of withering, the anther-lobes remained intact and closed. It would seem that these flowers, though structurally hermaphrodite, are functionally female only, and they are accordingly referred to henceforth as female flowers. It follows that self-pollination within the flower will not occur and that, to effect fertilization, pollen must be conveyed from some other flower.

In many instances the flowers of the inflorescence are of the same sex, all male or all female, but mixed inflorescences are by no means uncommon, a raceme which is mainly male having perhaps one or two female flowers towards the base.

A feature which impressed the writer during an early visit to a kola farm was that some trees were bearing chiefly male flowers while in others the female predominated. Was this then the secret of low-yielding and high-yielding trees ? Or did the kola tree pass through a phase in which it produced male flowers followed perhaps by a phase of female flower production ?

In an attempt to answer these questions, observations on the flowering of certain trees were made during three seasons. A weekly count was taken of all male and female flowers which could be seen from the ground and with the aid of a short ladder. From the records so obtained the following conclusions were drawn:

(1) No evidence was found of alternating cycles of male and female flowers in a tree. In most trees, however, male flowers predominated when blossoming was starting and finishing, at the beginning and ending of the flowering season.

(2) A sample of trees which had been planted from 16 to 18 years showed a mean annual production of 811 male and 638 female flowers per tree, a ratio of 1·3 to 1. Trees in a younger plot, from 12 to 14 years of age, however, produced fewer flowers, 612 male and 166 female per tree, a ratio of 3·7 to 1.

(3) While some of the trees in the older plot bore fewer female flowers than others, no tree bore none nor was prevented by absence of them from setting any fruit. Yet one tree on which 1,428 female flowers were counted during three years bore no ripe fruit in that time. In the highest-yielding tree about 14 per cent of the female flowers gave ripened fruit.

Fertilization of Flowers

It has been observed that many female flowers wither and fall without the setting of fruit at the end of two or three days, but the extent of this loss has not been assessed. It suggests that pollination is ineffective, the result perhaps of a scarcity of suitable pollinating insects or of some incompatibility or lack of fertility in the flower.

The flowers of kola have a penetrating smell which has elsewhere been likened to the smell of something dead, but which is actually quite distinctive and not altogether unpleasant. This is presumed to attract flies of different kinds which may then carry pollen from one flower to another. It is not known what are the species of insect concerned in pollination nor how effectively they perform this task.

Controlled pollinations have been carried out over a period of years in studies of inheritance of seed colour. For this purpose the inflorescence is enclosed in a bag of waxed paper a day or two before a female flower is due to open. When it has opened, pollen from a known male parent is applied to the stigmas on a matchstick. With practice, fair success has been attained and in 1953, when 139 flowers were pollinated, 59 per cent set fruit. *Table 3* which follows shows the results for eight trees in which self-pollination was done.

Table 3. Results of Self-pollinating eight Trees of C. nitida

Tree Ref.	*No. of flowers pollinated*	*No. retained after 4 days*	*No. which set fruit*
A	32	32	32
B	14	14	14
C	3	3	3
D	11	11	8
E	24	24	7
F	2	2	1
G	2	2	0
H	19	19	0

The complete failure in selfing tree H is in contrast to the success obtained in selfing other trees such as A and B. Three flowers of H to which pollen from a neighbouring tree was applied all set fruit. These results are hard to explain unless some character of the tree such as self-incompatibility is assumed. VOELCKER[56] records that, in the pollination of a number of kola trees in a plot at Ibadan, three trees were found which failed to set fruit on selfing, and he likened this to the incompatibility in cacao which had been demonstrated by POUND[74]. In later work on cacao, VOELCKER[76] showed that the pollination of a flower by incompatible pollen may cause a delay in abscission of the flower, which, however, finally falls without setting fruit. It is tempting to see in this failure to self-fertilize certain trees of kola a similar manifestation of self-incompatibility expressed by failure to set fruit accompanied by delayed flower-abscission.

On the other hand, it will be noted from *Table 3* that six out of eight trees did set some fruit when selfed, indicating that self-compatibility is the rule. There may be a ' range of compatibility ' here, as described in cacao

by Cope[64], in which he found that among compatible trees some were good, some medium, and others poor setters of fruit by their own pollen.

It has been shown by Lewis and Crowe[72] in a planting of plum trees containing self-compatible and self-incompatible varieties that, when pollinating insects are scarce or inactive, regular cropping may be restricted to compatible trees while the incompatible are marked by erratic or poor yields.

Loss of Young Fruits

As the young fruit is developing, a marked thickening of the peduncle normally occurs which brings support and nutriment to the growing fruit. Under Nigerian conditions the fruit is usually mature in from four to five months, considerably earlier than the seven or eight months mentioned by Sprecher von Bernegg[2] and others.

In the controlled pollinations which have been described, there occurred a heavy loss of fruit after the age of six or eight weeks and before maturity. The cause of this fruit drop (which took place after the writer's departure from West Africa) was not explained. It may have been insect attack, for in previous seasons fruits had been destroyed by caterpillars which bored into the developing follicles. There may also be in kola a fruit-shedding similar to the ' cherelle wilt ' of cacao described by Pyke[75], which Humphries[69] found to be associated with the supply of nutrients and water to the tree. But in kola the number of fruits set is normally small in relation to the bulk of the tree, and the water supply is abundant towards the end of the rainy season as the fruits are developing, so that one would hardly expect normal fruit production to impose an undue strain on the resources of the tree.

Effect of Wounding the Trunk

Many kola farmers in Nigeria hold the opinion that wounding the trunk with a cutlass is an effective way of causing the unproductive tree to bear fruit. The usual method is merely to deliver numerous blows at random on the trunk from ground-level to a height of 5 ft., so that the bark is penetrated by clean cuts with no fixed pattern or direction.

In Sierra Leone, Nisbett[41] tried ringing the tree in a more systematic manner by cutting out a strip of bark about an inch wide in a spiral from just above ground-level to the main fork, the turns of the spiral being about a foot apart and encircling the tree. Root-pruning was done as a separate treatment on other trees. Nisbett regarded his results as showing convincingly that the ringing treatment produced a substantial increase in yield while root-pruning was ineffective, but, since only 12 trees were treated by each method and actual yields of control and treated trees are not clearly expressed, the results are less than convincing to the reader.

If the great variability in yield, which is a feature of farmers' kola, is recalled, some idea will be formed of the difficulty of assessing the significant effect of any treatment such as this on the yield of trees. Nevertheless, an attempt was made to put the farmers' method to the test in one of the observation plots of kola maintained by the Department of Agriculture at Agege. Kola trees, 130 in number and all of good vigour and mature

age, were selected for experiment in 1952. From these, 40 trees were picked at random for the farmers' slashing treatment. It was intended as a second treatment to remove a ring of bark from other trees, but this was not carried out and in the end only the slashing treatment was applied and 90 trees remained untreated as controls. A local kola farmer was engaged to come and wound the trees when he thought the proper time had come.

This treatment proved to be less straightforward than had been assumed. According to the farmer, no ordinary tool would do, but only a new matchet not previously used for any purpose. Moreover, certain herbs had to be purchased, the nature of which was not disclosed, but which, dropped into water in which the knife was to be steeped, would ensure that fertility was transmitted to the cut trees. These requirements being met, the trees were wounded on a chosen day towards the beginning of the rains as the trees were in flush.

For each tree, whether treated or untreated, there was recorded the number of nuts harvested during the two years preceding the date of treatment and during the two subsequent years. As is normally found in any group of kola trees, there was wide variation in individual performance of the trees. Nevertheless, in the untreated trees the total yield was considerably less in the second period than in the first, whereas the reverse was true for trees subjected to slashing, their total yield being greater in the second period than in the first.

It has been possible to express this result statistically by counting separately the numbers of the treated and untreated trees which sustained (*a*) an increase, and (*b*) a decrease of yield after date of treatment, and by computing the probability of this result occurring by chance. Trees which ripened no fruit during the course of the experiment were disregarded. The figures are shown in *Table 4*.

Table 4. Showing Trend of Yield in Slashed and Untreated Kola Trees

	Number of trees		
	Slashed	*Untreated*	*Total*
A Yield greater in 2nd period	22	27	49
B Yield less in 2nd period	10	50	60
	32	77	109
C No yield in either period	8	13	21
Total	40	90	130

A marked difference in behaviour of treated and untreated trees is apparent in these figures. Employing the 'Test of Independence' as demonstrated by FISHER[66], it is possible to show that the probability of such a difference being due to chance and independent of the treatment is less than 1 in 100. It may be assumed, therefore, that the slashing of trees as done by the Nigerian farmer has a significant effect in improving yield in the two-year period following treatment.

In a few trees treated similarly at Ibadan, no obvious increase in the number of flowers or in the proportion of female to male flowers was

observed, and the cause of the increase in yield is more likely to be sought in improved set of flowers or reduced fall of developing fruit. This effect may perhaps be likened to the increased set and yield of apple fruits following the ringing of the bark on trunk or large branches, as described by HEINICKE[68], MURNEEK[73], and others, and the similar increases in yield of grapes obtained by girdling the stem at the time of blossoming as recorded by HUSMANN[70].

Likely Causes of Infertility in Kola

From such incomplete observations as are presented here, it is difficult to explain adequately the generally low level of productivity and the great variability in yield so typical of kola. Certain conclusions, however, seem to be permissible.

It is concluded that lack of female flowers is not an important cause of infertility and that we must rather look for a subsequent defect, such as inefficient fertilization or fruit shedding, to account for poor yield.

Many flowers have been seen to wither apparently unfertilized, possibly unpollinated. But, even when flowers are pollinated by hand, many may drop some days later with no fruit set.

Heavy loss of young developing fruits has been noted. The cause has not been explained and the dropping may either represent a shedding of the fruit related to inadequate supply of nutrients in the tree or a destruction of the fruits by pests. The wounding of the trunk, which has been shown favourably to affect yield, may perhaps act in this way by altering the nutrient supply to the branches and so reducing fruit shedding. Proof of this has yet to be produced.

While these causes, in one form or another, may explain the low yield of kola trees, they do not go far to show why some trees are consistently so much more productive than others. Inadequate pollination and the attack of pests might be expected to affect all trees in a plot, and the nutrient status of individual trees growing near one another in the same plot is unlikely to be so very variable. The existence of self-incompatibility, or of a range of compatibility, is suspected amongst kola trees, which, if associated with lack of active pollinating agents, would explain wide divergences in the yield of individual trees. This is advanced as a possibility worth exploring in future studies of kola.

The Inheritance of Colour in the Seed

The colour of seed produced by his kola trees is a matter of concern to the farmer, since the white and pale pink seeds usually fetch a higher price than the darker pink or red. Yet the behaviour of his trees in this respect seems unpredictable. While most trees produce mainly red nuts, some trees will give white, pink, and red. A single follicle may contain seed of different colours, and on occasion a seed has been found in which one cotyledon was red, the other pink or white.

Various reasons for this irregular behaviour are advanced by farmers. A common belief in Nigeria is that a tree which has been producing white nuts will give red if its roots come in contact with the roots of a neighbouring tree yielding red nuts.

Chevalier and Perrot, in describing the occurrence of red and white seed on the same trees and often in the same follicle and in proportions which varied from year to year, were unable to offer any explanation of the peculiarity to which they knew no parallel in the vegetable kingdom. They were driven to formulate the existence of four sub-species of *C. nitida*, of which *C. rubra* with only red seeds, *C. alba* with only white, and *C. mixta* with white, red, and pink seeds, were distinguishable by the colour of seed or flower alone. CHAMNEY[11a] in endeavouring to explain why trees which started by producing white seed should later bear pink, could find no Mendelian solution and concluded that seed colour was a function of the age of the tree.

VOELCKER[56], in his paper ' Cotyledon-colour in Kola ', did much to clarify the position. The first point he made is that the colour of the seed is the colour of the cotyledons of which it is mainly composed, and that these are the product of the mating of male with female parent. The colour factor of the pollen parent, as well as that of the tree bearing the fruit, affects the seed colour. This explains why a tree yielding white seed may produce some which are pink or red, and why the proportions of different colours may change from year to year depending upon the source of pollen.

Voelcker went on to show that a tree grown from a white seed produced only white seeds if self-pollinated or if fertilized by pollen from another tree grown from a white seed. On the other hand, fertilization of flowers on a white tree with pollen from a tree grown from a red seed might result in red, pink or white seeds being produced. He assumed the absence of colour to be a recessive character and its presence to be controlled by a complex series of genes.

The inheritance studies started by Voelcker have been taken some stages farther and the main conclusions are given here without going into details of individual pollinations. One difficulty in interpreting results may be mentioned. In the trade it is the custom to separate nuts into the three colours, white, pink, and red, and an attempt was made in this work to adopt the same grouping. The white seed, either without colour or sometimes with a faint greenish tinge, was unmistakable. But nuts classed as pink varied from a faint pinkish tinge to a deep rose and, since the red nuts also varied in intensity, a continuous range of deepening colour from pale pink to deep red was found. It therefore became a matter for judgment on the part of the observer as to whether certain nuts were classed as pink or red. For convenience in describing the results, the tree grown from a white seed is referred to as a ' white tree ' and its pollen as ' white pollen ', and similarly for pink and red.

Voelcker's conclusions, that a white tree selfed, or two white trees crossed, will yield only white nuts, were confirmed. Pink colour is dominant to white, and a seed with pink cotyledons may be either homozygous or heterozygous for pinkness.

Red colour is dominant to white and also to pink. A red tree may be homozygous for redness, in which event all its offspring are red, no matter what is the colour factor of the other parent. Alternatively it may be heterozygous, the result of a mating of a red tree with a white tree, or a red tree with a pink tree. In the former instance, if fertilized with white

pollen, the heterozygous red tree will give white and red nuts in approximately equal numbers, while in the latter instance pink and red nuts will be borne.

Despite the difficulty encountered from the continuous range of pink and red shades, it seems possible to explain these results by assuming the existence of two independent genes for pinkness and redness, the red factor being epistatic and masking the pink, as described by CRANE and LAWRENCE[65] in their example of colour in dahlia flowers.

SUMMARY

(1) An account is given of the known history of kolanuts and their recognition as the seed of several species of *Cola*.

(2) Four species of *Cola*, and three varieties, with edible seed have been distinguished in Nigeria and the British Cameroons, and are here described along with their distribution and uses. A key is provided enabling the species to be separated.

(3) A description is given of the farmer's cultivation of *C. nitida* in Nigeria and suggestions made for improving his practice.

(4) The yield to be expected from a planting of *C. nitida* is discussed and attention drawn to wide differences in performance of individual trees. The possibility thereby offered of greatly increasing yields by the careful selection and propagation of high-yielding trees is stressed.

(5) A study of the causes of low fruit production indicates that pollination is often ineffective. The presence of some form of incompatibility is suspected. There is frequently heavy loss of young fruits from a cause not yet known. Wounding of the bark of tree-trunks resulted in a significantly increased yield of mature fruits.

(6) Inheritance studies of cotyledon colour in the seeds have shown that pink colour is dominant to white, and red colour dominant to both white and pink.

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Further Observations on a Trial of Trees as Shade for Cacao

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INTRODUCTION

An observation trial of 15 tree species as shade for cacao was reported on by THOROLD[1]. The objective of the trial was to find one or more tree species which would be suitable as shade trees, but unaffected by the fungus (*Calostilbe striiospora*) associated with the disease of ' Immortelle trees ', principally Bocare Immortelle (*Erythrina glauca*).

The main conclusions arrived at by Thorold were:

(1) At an age of nearly five years from planting, none of the trees had developed symptoms of ' Immortelle Disease '.

(2) When a moderately high canopy was required, *Peltophorum ferrugineum* was worth further trial as a shade for cacao.

(3) Where a high canopy was desired, *Schizolobium excelsum* and *Parkia Roxburghii* appeared likely to meet requirements.

(4) Jiggerwood (*Bravaisia integerrima*) had made satisfactory growth and could serve as a cacao shade tree if required for conditions where the land tended to become waterlogged.

OBSERVATIONS 1946–1953

The tree species which were under trial are listed below:

Schizolobium excelsum Vog.
Parkia Roxburghii G. Don.
Peltophorum ferrugineum Benth.
**Machaerium Tipu* Benth.
**Sesbania grandiflora* Poir
**Poinciana regia* Boj. (Flamboyant)
Erythrina glauca Wild. (Bocare)
Bravaisia integerrima (Spreng.) Standl. (Jiggerwood)
**Tabebuia pentaphylla* Hemsl. (Pink Poui)
Erythrina Poeppigiana (Walp.) O.F. Cook (Anauca)
**Pithecolobium Saman* (Jacq.) Benth. (Saman)
**Hernandia sonora* L. (Toporite)
**Leucaena glauca* Benth.
**Pterocarpus Rohrii* Vahl. (Swamp Bloodwood)
**Crudia glaberrima* (Steud) Macbr. (Water Locust)

The trees were approximately five years old in 1945, when Thorold made his observations, and those marked with an asterisk were found to be unsuitable for one reason or another. In the period under review, *Machaerium Tipu*, *Pterocarpus Rohrii* (Swamp Bloodwood) and *Crudia glaberrima* have

died out, whilst Jiggerwood, *Bravaisia integerrima*, was cut out as it interfered with the growth of the cacao trees. As there were so few representatives (less than 10) of *Erythrina Poeppigiana* when the trial was established and the number has been reduced further, this species has, for purposes of comparison, been excluded from the trial. It should be recorded that observations made on specimens of this species, in close proximity to the trial, indicate that it can be a suitable shade tree for cacao in this locality.

Comparative data relating to height, spread, and girth are tabulated below for the species which were thought likely to be suitable as shade trees in 1945, with the exception of *Bravaisia integerrima* and *Erythrina Poeppigiana*.

Table 1. Comparison of Tree Species as Shade for Cacao

Tree	*Average height ft.*		*Average spread* ft.*		*Average girth† in.*		*Age in 1954*
	1945	1954	1945	1954	1945	1954	*years*
Peltophorum ferrugineum	30	50	24	34	16	42	13
Schizolobium excelsum	44	120	9	20	20	48	13
Parkia Roxburghii	42	100	16	50	25	60	13
Erythrina glauca	26	60	19	60	20	75	12–13

* Diameter of individual tree canopy
† Circumference of tree at approximately 4·5 ft.

It will be seen from *Table 1* that *Erythrina glauca* has the largest spread and a convenient height and, in addition, the conformation of its branches allows approximately 50 per cent light through to the cacao trees. *Schizolobium excelsum* has far too small a spread in proportion to its height and consequently gives a poorer shade and cannot be recommended as a suitable shade tree. *Parkia Roxburghii* has an adequate spread, branches high and, though somewhat on the tall side, provides adequate shade. A serious disadvantage, however, is its large buttress roots which spread up to 15 ft. and are a serious hindrance in the normal cultivation practices. Consequently, this species cannot be recommended as a suitable shade tree.

The growth habit of *Peltophorum ferrugineum*, owing to the conformation of its branches and tendency to form lateral branches at a relatively low level, does not provide the optimum light requirements for the cacao tree. This defect could possibly be controlled by pruning, especially as the tree is not large and is free from thorns. This species is recommended for further trial, provided the canopy is controlled by pruning.

It is of interest to note that none of the species, including the *Erythrina*, has developed symptoms of ' immortelle disease '. The apparent resistance to the disease of *Erythrina glauca*, in at least the first 12–13 years of its life, is of importance, in that it may still be used as a shade tree at least for a limited period, failing the finding of suitable alternatives. Disease apart, the periodic renewal of shade trees has much to be said in its favour.

SUMMARY

(1) Further observations are recorded on the performance of 15 tree species compared in an area of land (low-lying, liable to flood and heavy rainfall) where the ' Bocare Immortelle ' (*Erythrina glauca*) and, to a lesser

extent, the ' Anauca Immortelle ' (*E. Poeppigiana*), are liable to suffer from a fungus disease associated with *Calostilbe striiospora.*

(2) It is found that *Parkia Roxburghii* and *Schizolobium excelsum,* which appeared promising in 1945 when five years old, have developed unfavourable characteristics which preclude them from meeting the requirements of a good shade tree.

(3) Jiggerwood (*Bravaisia integerrima*) is not a suitable shade tree in that it tends to interfere with the normal growth of the cacao tree.

(4) It is confirmed that *Peltophorum ferrugineum* is worthy of further trial as a shade tree. The necessity for controlling the canopy by pruning is stressed.

(5) None of the species of trees in the trial is as suitable for shading cacao as *Erythrina glauca.*

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REFERENCE

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Book Reviews

TROPICAL SOILS : A critical study of soil genesis as related to climate, rock and vegetation

E. C. J. Mohr and F. A. Van Baren. N. V. Uitgeverij W. Van Hoeve, The Hague and Bandung; Interscience Publishers, Ltd. London and New York, 1954; 498 *pp.* with graphs, diagrams and photographic illustrations. £3 1*s* 0*d*

Since this book is categorically stated to be a critical survey of soil genesis as related to climate, rock and vegetation, and to deal specifically with tropical soils, it should be particularly interesting to serious students of tropical agriculture to whom few good books on soils are at present available. The book is really a revised and extended edition of Prof. Julius Mohr's ' Soils of Equatorial Regions ', translated from the Dutch by Dr. R. L. Pendleton of Johns Hopkins University, and published in mimeographed form in 1944. Prof. Mohr was formerly Soil Scientist in the Department of Agriculture, Buitenzorg (now Bogor), Netherlands East Indies and later Professor of Soils at the University of Utrecht. Both he and Dr. Van Baren, his co-author and former colleague at Buitenzorg, are now advisers at the Royal Tropical Institute, Amsterdam. Although the book purports to cover the whole of the Tropical Belt, much of the material is derived from the pedological studies of other authorities in Tropical America, Tropical Africa and the Pacific Region, so that a certain lack of balance is naturally to be expected. Greatest stress throughout is placed on parent rock as ' the mother of soils ', although the vital part played by climate, and particularly by soil climate, in soil formation is by no means neglected.

There are, in all, seventeen chapters of unequal length. The first and longest chapter (82 pages) deals with climatic aspects and includes detailed consideration of such important matters as rainfall, evaporation and transpiration, infiltration, percolation and retention in soil, soil temperature and soil aeration.

In the reviewer's opinion this is one of the best sections of the book in that it provides a useful summary of modern views on the static and dynamic relationships of soil moisture, and discusses ' what happens to the rain ' in various places in the wet and the dry tropics. It also summarizes the recent studies of Prescott in Australia, Mohr in Java and Hardy in Trinidad in relation to the conclusions reached by Thornthwaite in U.S.A. and Penman at Rothamsted, England.

The next six chapters (166 pages) concern the mineralogical aspects of soil formation and are mainly factual. Rock weathering in different tropical regions where it has been studied in detail is discussed in the longest of these (45 pages). The work of Harrison in British Guiana here receives full consideration, based as it is on the detailed chemical analysis and petrological examination of large numbers of samples of igneous and metamorphic rocks and their weathering products. The vexed question of the petrogenesis

of so-called ' primary laterite ' is critically discussed, and also the formation of certain kinds of ' lateritic ' soil and of ironstone concretions. Clay mineralogy is concisely treated in another long chapter (32 pages) and the mineralogy of the coarser soil fractions in another (42 pages).

The part played by vegetation in soil formation can scarcely be overstressed, and full justice is given to this subject in Ch. 8 (19 pages). The effects of temperature and soil moisture on the build-up and break-down of soil organic matter and the role of micro-organisms in these processes are fully dealt with.

The genetics of tropical soils are considered in the next three chapters (63 pages), in which the efficacy of the main contributory factors, namely, temperature, water-movement, soil-air, nature of soil parent material (weathered rock), organic matter and time, is assessed and compared for different tropical regions, particularly Indonesia.

' Lateritic soils ' receive a long chapter to themselves (Ch. 12, 44 pages). ' Laterization ' is defined as ' the leaching out and elimination of silica, alkalies and alkaline earths and the concentration of (hydrated) iron and aluminium oxides, the latter being ' partly recombined with silica '. Instead, however, of starting with a discussion of the features, origin and possible mode of formation of ' laterite ', as named and first described by Buchanan in his ' Journey through Mysore ' in 1807, the authors prefer to accept this chemical definition of laterite, which unfortunately crept into the literature as a result of the chemical analysis, in other parts of the world, of certain weathering products of basic igneous rocks which turned out to contain rather large amounts of free gibbsitic alumina. Eventually, when Buchanan's laterite came to be chemically analysed in 1925, its typical ferruginous and siliceous composition, and its essential property of setting hard, as brick (Lat. ' later '), on drying, became fully recognized. Its true origin, however, was not understood until Marbut, in 1930, noted the striking similarity between Buchanan's laterite and material (iron-pan) comprising the B-horizon of a well-developed hydromorphic soil occurring in the Amazon basin. This material set very hard on drying and probably consisted mainly of hydrous ferric oxide, kaolinite and quartz. Marbut gave the name ' Ground Water Laterite ' to this soil, and included it in his Intrazonal World Groups. Buchanan's laterite may thus comprise the material that forms the hard resistant table-land cappings that are such a conspicuous feature of the scenery of Tropical Africa, having been originally developed in late Miocene or Pliocene times when Africa was mostly a vast low-lying swampy peneplain, and subsequently elevated, denuded, desiccated and indurated into ironstone gravel, ironstone crusts or ' cuirass '. Had this approach been adopted, the interesting material which the authors have accumulated from the literature might more logically have fallen into line.

' Podsolic soils ' are dealt with in the next chapter (Ch. 13, 12 pages), wherein the authors accept the notion that they do occur in the tropics, even at low altitude, under conditions of high rainfall and free drainage, though they do not insist that the last condition is necessarily essential, which thus leads to some confusion with the hydromorphic group of soils.

' Margalitic soils ' are next described (Ch. 14, 24 pages). These are considered as embracing what have been variously called ' black cotton soil ',

'Regur soil', 'black turf', 'marl soil', 'tropical Rendzina', *etc.* They are deeply cracking, 'self-mulching' clay soils whose component clay mineral is chiefly montmorillonite. They commonly develop over intermediate and basic volcanic rocks. Their profiles contain calcium carbonate concretions, and they are usually formed under rather dry climatic conditions. Several examples are described in detail in this chapter, and the reason for their black colour is discussed.

Other important soil-types are described in Ch. 15 (35 pages); they include mostly tropical soils of dry regions with which the authors admit they have not had personal experience, for example, desert soils, alkali soils, steppe and savanna soils, plains soils and plateau soils (described by G. Milne in East Africa), hardpan soils (possibly analogous with planosols), limestone soils (Terra Rossa) and Ando soils (volcanic ash soils).

The last chapter of the book (Ch. 16, 17 pages) is devoted to the vexed question of classifying tropical soils. Grouping on physical properties (as colour, texture, structure, permeability, shrinkage, *etc.*), or on chemical properties (as organic matter content, base exchange capacity, exchangeable base contents, silica-sesquioxide ratio, reaction, *etc.*), or on mineralogical composition, is ruled out because the properties of each layer of the profile would have to be described separately and it would thus be impossible to form a clear picture of the soil as a whole. Moreover, many of the properties mentioned cannot be determined rapidly in the field, that is, they are not really mappable features.

Grouping according to the degree to which soil formation has been decided by the operation of the five chief soil-forming factors, namely, rock, climate, vegetation, topography and time, is also unsatisfactory because it describes the soil by reference to factors external to itself and not by utilizing its own characteristic features such as its general morphology.

Without committing themselves to any particular scheme of classification, the authors of this book briefly describe systems at present in use, such as Marbut's system (1927), later developed by Thorp and Smith (1949), now in current use in U.S.A., and also the Catena idea introduced by Milne in 1935 for the purpose of simplifying the grouping and mapping of the soils of East Africa. They conclude by recommending (1) that differentiation of soil groups into Pedalfers and Pedocals should be retained, (2) that grouping under Zonal, Intrazonal and Azonal categories should be dropped, (3) that the terms 'soil-series' and 'soil-type' should be more clearly defined, (4) that the whole profile should be used as the unit of classification, and the fullest qualitative and quantitative information whereby its features may be described should be compiled, (5) that identification terms of a geographical nature should not be used in naming soil denominations, but rather that 'identification keys', based on the soil's fundamental features, should be devised, and (6) that, as an aid to the last objective, an international collection of tropical soil monoliths and colour photographs of them should be made.

There is no doubt that this book will be much used by serious students of tropical soils. It is a mine of information and a magnificent compilation of material widely scattered in the literature and inaccessible to most tropical workers. Many of the discussions are both illuminating and

stimulating. If criticism must be made, it might be justified to state that the treatment is rather irregular and the stressing not quite consistent. The discussions in some cases are left somewhat in the air, but this is perhaps unavoidable because of the paucity of factual knowledge concerning many aspects of tropical soil science. Students owe the authors a deep debt of gratitude for their grand effort, and the translator is to be congratulated on his share of the work. The binding and the printing of the tables, diagrams, illustrations, indexes and reference lists alike are excellent.—F.H.

MEANS OF INCREASING RICE PRODUCTION

F. G. De Geus. Centre d'Étude de l'azote, Geneva, 1954. 143 *pp.* (illus.)

In the foreword of this book is found the following:

> ' This book does not claim to be a complete handbook for the rice grower but it stresses the possibilities of increasing rice production by means of efficient fertilising . . . '.

Insofar as the claims for the foreword are maintained the title is misleading since it carries the implication of discussing, in general, the possible methods of increasing rice production.

Those sections of the book concerned with the subject of fertilizing rice are extremely good. The author has gathered together information from various sources and countries in a concise and readable form which makes it possible to obtain a general picture of rice fertilizing practices throughout the world. Furthermore, where possible, data from relevant experimental work is also presented from which the reader may draw his own conclusions.

The parts of the book concerned with rice production methods in various countries of the world and which provide data on the annual volume of production in these areas are also of great value, and again, by virtue of their concise form, are extremely useful for a general rapid review of the subject.

However, various other factors concerned with the production of rice are dealt with in a very sketchy manner and sometimes there are tendencies towards over-simplification resulting in misleading statements. For instance, in the section on ' Cultural practices in rice growing ', the paragraph concerned with the effects of light makes no reference to photoperiodism, which is of the utmost importance, although mention is made of the possibility of light deficiency.

As a source of information on fertilizer practices and fertilizer requirements for rice, this book is of considerable value; as giving an up-to-date survey of world rice production the publication is of interest. The sections on other factors influencing rice production should be either improved or omitted.—P.H.R.

PROGRESS IN THE PHYSIOLOGY OF FARM ANIMALS, VOL. I

J. Hammond (Editor). Butterworths Scientific Publications, London, 1954. vii + 392 + xv *pp.*, 122 illus. 45*s*

Volume one of this new series of three volumes embraces eight contributions from authors who have each distinguished themselves in their respective

fields of animal production. It is difficult, therefore, to cover in detail such a composite volume within the space of a brief review.

The first four sections cover four aspects of animal nutrition. ' Ruminant nutrition ' is discussed by K. L. Blaxter and ' Pig Nutrition ' by R. Braude ; W. Bolton deals with ' Poultry nutrition ', and D. P. Cuthbertson surveys the subject of ' Trace Elements '. Whilst the principles discussed in all these four sections may be applicable for the most part to tropical conditions, the tropical worker cannot but read these sections with a heavy heart, since they emphasize how little is known about animal nutrition in the tropics.

The same argument does not apply to the last four sections of this book, all of which have much significance for those engaged in tropical animal production. Section five consists of an excellent discussion by Norman Wright of the ' ecology of domesticated animals '. In the opinion of the writer this section represents the best published discussion of this subject to date. The application of the rules of Bergmann, Allen and Wilson to domesticated livestock are fully discussed, and Wright concludes his interesting chapter by emphasizing the importance of environment in animal production. This subject is further stressed by J. D. Findlay and W. B. Beakley in section six, which is largely concerned with the environmental physiology of cattle. These authors have, wherever possible, referred to other species, but most of the known information appears to relate to cattle.

J. C. D. Hutchinson gives an account of ' Heat regulation in birds ', and explains the main differences between the processes employed by mammals and birds to maintain a constant body temperature. This subject has recently received the attention of several workers and it is now possible to obtain useful information, the application of which has economic importance for poultry keepers in both hot and cold regions.

The contribution of N. T. M. Yeates in section eight concerns the influence of light upon the behaviour and functions of farm animals. The implications of the photo-periodicity on reproduction, moulting, growth and milk production are all dealt with. The importance of this subject to the animal husbandman in the lower latitudes is great, but unfortunately the bulk of the information available has been garnered in temperate areas.

All sections are, wherever possible, illustrated with diagrams, graphs, tables and pictures. Each section constitutes a concise discussion of the basic information on the subject, interlaced with a review of recent work. This type of book is invaluable to tropical workers who are often cut off from many sources of information.

It is appropriate that the book should be edited by the doyen of animal physiologists, Dr. John Hammond.—J. R. H.

HISTORY OF THE BRITISH WEST INDIES

Sir Alan Burns. George Allen & Unwin, Ltd., London, 1954. 821 *pp.* (illus.) 70*s*

An historian can probably undertake no more difficult task than a comprehensive history of the British West Indies. The territories are dissimilar and dissociated from each other physically, geographically and politically

as well as historically; indeed, today, in spite of many gropings towards political federation, the British West Indies are still not a unit in any sense of the word. Rippling over this local mosaic are the shifting political currents of the contending metropolitan countries in Europe for the past three centuries. Just like the clear rippling water of the Caribbean itself, these currents momentarily distort and exaggerate tiny fragments below. It is difficult, for instance, to imagine today conditions in which islands the size of St. Kitts or St. Vincent were divided between two European powers and caused friction between them.

Sir Alan Burns is well qualified to undertake this most difficult task. He was born and lived for many years in the West Indies and is, by training and natural gifts, able to write clearly and at the same time attractively; somehow during his busy life he has managed to carry out a prodigious amount of research. This book is indeed one for reference rather than light entertainment and if sometimes we feel that the mosaic consists of too many tiny fragments for the best overall artistic effect we must remember that the history of the British West Indies is a most complicated series of interlocking stories. As a handsome, complete and well annotated history, this book has as yet no rival—A.L.J.

COCOA

D. H. URQUHART. Longmans, Green and Co., London, 1955. xix + 230 *pp.*, 10 colour plates and 97 photographs. 35*s*

Almost every research worker and agricultural officer concerned in the growing of cocoa must have experienced the query from planters seeking information on the crop—' What general book can you recommend ?' Instead of, ' Well, there is Van Hall's Cocoa but it was written in 1914 with a second edition in 1932', it is now possible to say, ' ' Cocoa ' by Urquhart, just published, well produced, with excellent photographs and illustrations'. This book follows Grist's ' Rice ' in the Tropical Agricultural series, and aims at putting between two covers all the available information that can be of value to the cocoa planter. Besides his own wide experience of the crop, the author has been able to draw on specialists for certain of the problems concerned.

After a brief historical introduction, the botany of the crop is dealt with in a clear and concise manner by the late Professor R. E. D. Baker. Then, following a chapter on the main climatic determinants, comes an account of cocoa soils by Professor F. Hardy. The physical and chemical factors affecting growth are dealt with in a manner readily grasped by the non-specialist, and some of the difficult problems associated with replanting on worn-out soils are described.

Four chapters deal with the practical methods of establishing a plantation, bringing it into bearing, and the harvesting and processing of the crop. Vegetative propagation by rooted cuttings is dealt with in considerable detail (p. 53 has the only misprint noted, *i.e.* ' pathologist ' for ' physiologist ') but some details might have been given as to why vegetative clones should be used in preference to seedlings, of the standards adopted for their

selection, and the problem of incompatibility. It is perhaps assumed, however, that planters intending to practise vegetative propagation will use proven clones. In dealing with the question of shade, the strong interaction between the supply of mineral nutrients to the tree and the amount of shade for optimum yield might have been indicated.

The next two chapters deal with the two extremes of cocoa culture; peasant culture in West Africa and rehabilitation in Trinidad, the latter by Professor C. Y. Shephard. The extreme simplicity of the system evolved in the Gold Coast and Nigeria makes a marked contrast with the detailed operations listed in scientific rehabilitation. Until the appearance of Swollen Shoot, the methods of the West African, though superficially very crude, resulted in the production of cocoa with the minimum of labour. It depended, however, on the exploitation of virgin forest soils and the note of warning has already been sounded that these will soon be used up. The modern viewpoint that cocoa should cease to be a forest crop and become an orchard tree crop producing high yields with scientific care and attention follows. Pests, fungal and virus diseases are next described together with methods of control. Quality and grading are dealt with and the types of cocoa required by manufacturers are listed.

To the research worker associated with the crop the feeling may arise that the chapter on research is perhaps rather superficial, but this is perhaps inevitable in a book which aims at being practical rather than thought-provoking. The book concludes with a number of appendices covering such matters as soil surveys, costs for estates and peasant farms and small-scale fermentation. Each chapter carries a list of selected references.

In his foreword, Sir Geoffrey Clay, Agricultural Adviser to the Secretary of State for the Colonies, speaks of cocoa as a favoured crop in the sense that, with the world shortage of this commodity that now exists, producers can look forward to a fairly rosy future for many years. The fact remains, however, that even apart from virus and other diseases, most producers must face the replanting or rehabilitation of gradually ageing trees and soils. For this, new knowledge and new techniques appear essential and the more knowledge that can be brought to the planter the better. The author is therefore to be congratulated on this book which will bring to the planter (and particularly the new planter) so much of the information he must needs acquire.—D.B.M.

SYMPOSIUM ON THE GEOGRAPHY OF PUERTO RICO

Edited by Clarence F. Jones and Rafael Pićo. University of Puerto Rico Press, Rio Piedras, P.R., 1955. 503 *pp.* (illus.)

This book is the outcome of an invitation issued to and accepted by the Department of Geography of the North-Western University, Evanston, Illinois, United States of America, in January 1949, by Dr. Rafael Pićo, Chairman of the Puerto Rico Planning Board, to undertake a land-use survey of Puerto Rico and the construction of a land-use map. The field work was begun in July 1949, by a team consisting of two members of the Department of Geography of the North-Western University and one member

of the Social Service Research Centre of the University of Puerto Rico which undertook a preliminary pilot study in order to develop and codify appropriate systems of mapping and of interviewing representatives of the agricultural industries, and to incorporate the work that had already been done by various government agencies, such as the U.S. Forest Service in Puerto Rico, the Soil Conservation Service, the various agricultural experiment stations, and the Puerto Rico Department of Agriculture. The procedures evolved were tested in a north-to-south traverse right across the island and in fifteen selected sample areas embracing most of the main areas of differing land-use and land characteristics. This preliminary work took nearly three months. The mapping was done on aerial photographs on a scale of 1 to 10,000 ($6\frac{1}{3}$ in. to the mile).

The next stage was to expand the pilot study into an island-wide scheme of field mapping. The whole area was divided into 18 units which were not based, however, on land characteristics but on municipal boundaries, so that the statistical data which had already been compiled within these political units could be employed in the land-use survey. The mapping units varied in size from 125 to 289 square miles. Each unit was mapped by a team of three, comprising a chief and a deputy-chief, both graduate students in geography, and an interviewer who was a Puerto Rican having some knowledge of local agriculture. The deputy chief usually served for four to six weeks, after which he became the chief of another team.

The techniques used in the field mapping, and the system of fractional notation applied within each unit area to the recording of the kind and quality of the crop, the kind of soil, the slope, degree of drainage, erosion damage, stoniness and so on, and the method of entering the data onto aerial photographs, are all described in considerable detail. Concurrently with the field mapping, the interviewer selected, on a random sample basis, the farms or houses required for interview and recorded the results of his interviews on a standard form. The sampling ratio used was one out of every eight large farms, one out of every 16 'parcelas' (less than about 3 acres in size), one out of every 32 share-croppers, and one out of every 64 rural dwellings. These ratios are based on the total number of each of these classes in the entire island. The field work for the 18 mapping units was completed between September 1949 and August 1951, and took about 220 man-months of work, including that of the interviewers. 'Unquestionably, this programme provided the most complete inventory of land-use ever made in Puerto Rico and probably the most detailed survey of its kind in a tropical area of this size.'

The financing of this ambitious project is briefly described. The local sponsor at the start was the University of Puerto Rico; it was joined later by the Department of Agriculture and Commerce, special funds being provided by the legislature. A speeding-up of the programme was urged in June 1951. Advanced students of other universities besides the North-Western were accordingly recruited, which helped in the staffing of the 18 mapping units and ensured the completion of the work in the autumn of 1951.

The contributions to this book are based upon the actual field work carried out within the individual mapping units. They are essays or

dissertations written by actual participants in the land-use survey. In all, there are 18 essays. The first fully describes the conduct and findings of the pilot study and the development of the survey techniques finally adopted. The second deals with the classification of land-forms. Other essays severally describe the dairy industry of San Juan, the pineapple industry, the sugar cane economy of Mayaguez, cattle farming in the south, and the coffee industry of the western highlands. Others describe regional studies of specific areas such as the limestone belt of the north-central part of Puerto Rico, the hinterland of Isabela, the south-western region, the south-eastern region, the Caguas-San Lorenzo region, the Upper Loiza basin, and four other special areas. The last essay discusses the uses made of the rural land classification data. There are 186 illustrations, consisting of maps, diagrams, photographs of landscapes and farm buildings, 13 plates in a folder at the end of the book giving details of land-forms, land-types, land-use, land-utilization and so on, and 59 tables of selected data. There is also a full index. The printing and binding are most attractive.

The motives for the initiation of this work, according to the Preface, were the high population density of Puerto Rico, the acute land pressure and the kind of use being made of the potentialities and resources of the Island which were thought to require a thorough ' stock-taking ' prior to better land-use planning ' that will insure individual survival and if possible elevate the material level of living for the people '. It is to be hoped that the attainment of these deserving objects may effectively be furthered through the completion of this survey by the worthy band of enthusiasts who have contributed so much to its successful accomplishment.—F.H.

CROP PROTECTION

G. J. Rose. Leonard Hill Limited, London, 1955. 223 *pp.*, 113 illus. 30*s*

This publication is written as a practical guide to farmers and small-holders who, being concerned with crop production, are faced with problems of disease and pest control and of weed infestation. It is written in simple terms and covers the whole field of chemical formulations and equipment, insecticides and fungicides, application machinery and the protection of stored products. In the sections dealing with weedkillers the author has provided a brief but adequate summary of those commonly used in commercial practice, and although the space devoted to each is necessarily limited, the principal properties of interest have been satisfactorily dealt with. Some 67 pages describe, in considerable detail, various types of dusting and spraying machinery and the maintenance of equipment of this nature. The discussion ranges from hand dusters and sprayers, through knapsack and tractor-mounted equipment of various types, to spraying and dusting by aircraft; mention is made also of soil injectors, mistblowers and fogging machinery. In this section also there is a useful chapter on ' choosing, operating and maintaining equipment ', an important aspect which is sometimes overlooked.

A book which sets out to cover in one volume and in popular form the whole range of chemical-mechanical aspects of crop protection cannot of necessity deal in great detail with each branch of the subject, but, with

this limitation, the author has succeeded in giving the reader a well-balanced account of modern crop protection methods. The old-fashioned reader, bearing in mind that prevention is better than cure, might comment that more could have been said on the part that good husbandry can play in the production of healthy crops.—A.B.K.

ABSTRACT BIBLIOGRAPHY OF COTTON BREEDING AND GENETICS, 1900-1950

R. L. Knight. Commonwealth Bureau of Plant Breeding and Genetics, Cambridge. Technical Communication 17, 1954. 256 *pp.* 21*s*

This book, which will appeal to specialist, teacher and student alike, contains nearly 1200 references covering the most important papers in half a century's literature on one of the world's major economic crop plants. Each paper is briefly abstracted. Three appendices give (1) the classification of the species genoms, (2) a gene list for the genus, and (3) linkage groups. An adequate subject-matter index enhances the usefulness of the book.

F.W.C.

AN ANNOTATED BIBLIOGRAPHY OF RICE SOILS AND FERTILIZERS

G. V. Jacks and M. Kathleen Milne. Commonwealth Bureau of Soil Science, Harpenden. F.A.O. Rome, August 1954. 180 *pp.* 7*s* 6*d*

This is a compact compilation of over 900 references summarizing briefly the results of work which has been done on the rice crop in all producing countries. The bibliography is divided into three main sections dealing, respectively, with soils, cultural practices and fertilizers, and it embraces the period 1929 to 1954. A very useful reference book to those in any way concerned with rice production.—A.B.K.

OBITUARY

Charles T. Watts, M.I.Mech.E., M.A.S.Ref.E., M.Inst.R.

Mr. Charles Tilden Watts, College Engineer and Technical Assistant, died on 7th March 1955, after a long and painful illness. He was sixty years of age and had served the College since its inception in 1922 as the West Indian Agricultural College. He was the son of our first Principal, Sir Francis Watts, who was previously Commissioner of the Imperial Department of Agriculture for the British West Indies, with headquarters in Barbados. Before joining the College Staff, Mr. Watts had gained engineering experience in the United States where he worked for some time with a well-known firm of motor-car manufacturers. He had also later been connected for a short time with a fertilizer company operating in the West Indies. He was consultant for several engineering firms and other organizations, and for a large commercial sugar factory. He was also responsible for the maintenance and running of the College experimental sugar factory which he saw being constructed in 1924, and which was ever his special delight. He supervised the erection of many of the College residential buildings and laboratories, such as the students' hostels, the chemistry building, many of the staff houses and farm buildings. The attractive appearance of the College grounds, which always pleases our visitors, is largely owing to his constant supervision.

Mr. Watts' activities were not solely confined to College matters. He was superintendent of the Northern Division of the Special Reserve of Police and was awarded in January 1946 the Colonial Police Medal for his services to the Special Constabulary of Trinidad.

Mr. Watts was a loyal and trusty friend to those who knew him well. His was a generous and kindly nature, even though he tried often to hide it under a diffident exterior. He greatly loved a joke and he could be a most amusing companion. He possessed the valuable gift of being able to extract the best out of the men working under him, and the fact that he might at times have been regarded as a rather severe task-master could be explained by the high standards he always set for himself. Students at the College will remember him for the help he gave them in acquiring and disposing of their second-hand motor-cars. His shrewd knowledge of human affairs, and of men and their motives, was always at the disposal of anyone who asked for his advice. It will be hard to imagine the College without ' Charlie '; his familiar presence among us had become a commonplace experience in our daily lives.

Among his close relatives who mourn his passing are his wife, Carmela, his son, Claude, his two married daughters, Mrs. John Sumner of U.S.A., and Mrs. Victor Philipps of Trinidad, his younger brother, John, in England, and his two sisters, Lady Grannum and Mrs. Austin. To them we offer our sincere sympathy in their loss.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

A Report on Cacao Research, 1953. 10*s* 6*d*

Reprints are available, at varying prices, of articles in the Cacao Research Reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao (1945–1951 Report)—Price 5*s* plus postage.

Memoirs—Economic Series No. 2: Peasant Farming: Report on Peasant Experimental Farms at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., by A. L. JOLLY. 1*s*

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

Volume I Ranunculaceae to Araliaceae complete in eight parts and index. 26*s* 6*d*

Volume II Part 1. Rubiales. 2*s*
Part 2. Asterales to Primulales. 3*s* 6*d*
Part 3. Ebenales to Polemoniales (in part). 5*s*
Part 4. Polemoniales (in part). 5*s*
Part 5. Scrophulariaceae to Acanthaceae. 5*s*
Part 6. Verbenaceae and Labiatae, in the press.
Further parts are in preparation.

These and other publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad.

Peasant Experimental Farms[1]

A. L. Jolly

Lecturer in Economics, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

INTRODUCTION

The Peasant Investigation at the Imperial College developed out of a number of economic surveys conducted in the West Indies between 1938 and 1945. These surveys revealed many overwhelming handicaps, such as inadequate land and capital, unsatisfactory land tenure, fragmented, non-residential farms and so on, under which most peasants worked. It was concluded that the fundamental question of what was the potential role of the peasant in West Indian agriculture could not be answered by further surveys of existing conditions; it would have to be asked of unit farms on which the handicaps could be removed and management purposefully directed to the achievement of permanent profitable agriculture. If such units proved successful they would provide valid evidence of the need for ameliorating the handicaps; if they did not, too much energy and sentiment should not in future be wasted on the peasant.

Between 1946 and 1950 five unit farms were established on the College old farm area. They were (1) Manual Arable, (2) Arable Dairy, (3) Draught Oxen, (4) Specialized Dairy, and (5) Market Garden. In the early years these holdings demonstrated, greatly to the frustration of the investigators, the lack of any proven procedure for conducting unit farm experiments; gradually workable procedures were evolved and these have already been summarized in this Journal[2]. If the investigation had achieved nothing else it certainly pioneered sound methods of carrying out farm management research by means of unit farms.

On all the five farms there were laid down three conditions which were considered, and have since proved, essential to successful small-scale farming on the particular land used. First, all were required to be unfragmented, resident farms and the labour force on each was required to live in the house provided. Second, all were required to provide full-time employment throughout the year for the labour unit without the assistance of seasonal hired labour. Certain modifications to this restriction were allowed so that work for which the farmer was not qualified or for which his farm was not equipped, could be done by hired labour. Any seasonal shortage of regular work, however, was considered a defect of the farm organization which had to be rectified. Third, all farms were required to practise a system of mixed (*i.e.* crop and livestock) farming so that pen manure would be manufactured for application to the land. This condition was somewhat modified in the case of the Specialized Dairy.

In other respects the maximum elasticity was allowed. For instance, there was no restriction on any of the farms as to the area of land cultivated provided that the gross income was at least \$250* per acre, that is about the

* \$1 (B.W.I.) = 4*s.* 2*d.*, \$4·80 = £1.

average of similar land under estate sugar cane; nor on the capital employed, provided that the investment was expected to be profitable and was within the definition of the particular farm; nor on the production of any one crop or the consumption of any one resource, provided that the overall system represented a reasonable combination of crops and livestock. It so happened that all five farms could be operated by the minimum labour unit of one man and one woman, but no restriction was imposed in this respect and larger labour units were at times considered. The smallest unit farm is obviously the least costly to operate and the findings can be multiplied up if estimates are required for similar farms to be worked by larger families.

ESTABLISHMENT

The initial problem was housing. Many land settlements in the West Indies had shown clearly the danger of sinking too much money in the farmer's house so that little or none was left for more directly productive investment in his farm. It was decided, therefore, that all units should in the first place be provided with the minimum cost housing compatible with health and sanitation, and the construction of such buildings in itself provided a lesson for land settlement. Information was collected from every possible source on building materials and design and a house of tapia (dried mud) walls with thatch roof was finally decided on for all. The cheapness of this design arises from the fact that the wall material can be manufactured on the site and some of the building and most of the repair work can be

Table 1. Cost of Erecting Buildings (1947)

Particulars	*Quantity*	*Cost*	
		$ c	$ c
Labour			
Skilled	292 hr.	84·79	
Unskilled male	1,022 hr.	192·98	
Unskilled female	115 hr.	16·92	
Peasants	311 hr.	82·39	
		——	377·08
Materials			
Lumber:			
Ground pillars	15	6·00	
Frame posts	56	28·00	
Frame posts	36	8·64	
Rafters	63	12·60	
Rods (roof and wall runners)	21 bundles	12·60	
Other		1·19	
Floor, window and door boarding	300 sq. ft.	72·74	
		——	141·77
Thatch:			
Timite thatch	7,800 leaves	71·70	
		——	71·70
Other:			
Tapia grass	1 cart load	1·00	
Wood preservative	2 gal.	2·00	
Hardware		27·18	
Cartage of materials		16·12	
		——	46·30
Total cost			636·85

undertaken by the peasant himself; the framework of the house is simply constructed of local round wood, Olivier (*Chuncoa obovata*). Raised pinewood flooring was provided for the living rooms, but no window glass was used at all. The cost of a typical house in 1947, with kitchen, latrine and small cattle pen, is given in *Table 1*. The cost of building material has increased by perhaps 20 per cent since 1947, but the design is still the cheapest that can be constructed in this district. The houses generally have worn well and the oldest is still in sound condition at seven years of age.

Since every one of these farms required modification before it gave satisfactory results the cost of establishment in their original form is of little interest. The estimated costs to establish them in their final form are given in *Table 2*. It became obvious during the course of the investigation that on

*Table 2. Tenant Capital required for Units in their Final Form (excluding landlord investment in land, water-supply and roads)**

Type of farm	*Manual Arable*	*Arable Dairy*	*Draught Oxen*	*Specialized Dairy*	*Market Garden*
Acreage	3·6	5·1	6·7	7·5	1·2
			Cost—$		
House and pen	1,000	1,100	1,200	615	863
Byre	—	—	—	720	—
Implements and tools ..	50	80	700	180	15
Livestock	255	800	1,060	1,500	200
Grass	112	450	240	640	65
Crops	1,444	1,075	1,946	—	300
Risk capital	—	500	—	3,500	500
Total cost	2,861	4,005	5,146	7,155	1,943

* These farmers are assumed to be tenants and their farms are charged rent at between $10 and $13 per acre to maintain and amortise landlord's capital. No charge is made for the amortisation and interest on tenants' capital, but depreciation is charged on these assets.

livestock farms some financial provision would have to be made for the losses which are likely to be incurred during the period of establishing a profitable herd. Any farmer who previously had built up a satisfactory herd on another type of farm could establish himself on an arable or specialized dairy farm at rather less cost than is shown in the table. A similar provision has been made for the market gardener because he will take some time and incur some loss in learning the finer points of the skill-demanding crops on his particular farm.

ARABLE FARMS

The three arable farms form a natural group and their histories are in some respects similar. These farms suffered from what proved to be a false start in the first four years because the cropping programme was unprofitable and unsuitable to all of them. The original rotation was suggested by the crops most favoured by peasants in the district and it was assumed that combining them with livestock and arranging them in an orderly rotation would automatically result in a profitable farm. The crops were rotated as follows:

(1) Yams (pen manure applied).

(2) June-planted soya beans; October-planted maize.

(3) Pigeon peas intercultivated with soya beans.
(4) June-planted maize; October-planted sweet potatoes.
(5) Plant cane (pen manure applied).
(6) Overyear cane.
(7) 1st ratoon cane.
(8) 2nd ratoon cane.
(9) 3rd ratoon cane.

Most of the crops yielded well and far better than those of neighbouring peasants, but the rotation had to be judged a failure because it resulted in earnings of between $400–$600 per farm, or only half the minimum required. It had been decided that the minimum earnings on which permanent peasant farming in Trinidad could safely be founded were the equivalent of current wages of the workers for full-time employment throughout the year (from $900 at the beginning rising to $1,200 by 1953).

Table 3. Constitution of Four Years Loss on Manual Arable*

Losses (deficit below wages)		*Profits (surplus above wages)*	
	$		$
Maize	176·59	Yams and cassava	75·50
Pigeon peas and soya bean	152·09	Cane	50·60
Sweet potatoes	99·87	Rice†	20·60
Vegetables	31·38	Livestock	153·73
Buildings	377·71		
Deadstock	45·11	Net loss	752·57
Holding maintenance	170·25		
	1,053·00		1,053·00

* Profits and losses are the margins between revenue and the expenditure after charging wages for work performed on the enterprise. Since the minimum satisfactory labour income for the whole farm must equal current wages for full-time employment, an enterprise showing a profit has exceeded the required standard, one making a loss has fallen short by that amount.

† Worked in private time with help of neighbours.

The limitations of the rotation are well illustrated on the Manual Arable holding. Over the first four years the deficit below wages of $750 was accumulated in spite of some lucky trading in livestock which resulted in a rather spurious profit of $154 on this enterprise (*Table 3*). The important feature of this profit and loss account is that with the exception of rice (which was grown for two years under different conditions from the other crops), the short-term crops so typical of peasant farming showed losses, whereas yams and cane showed profits. On the three arable farms in three years, cane and yams yielded a labour income* of $1·84 per day worked on them, short term crops only 56c per day. Furthermore, the short-term crops were most demanding as to labour, particularly for weed control in July and August; this heavy demand limited the total area that could be cultivated so that a slack period developed at the end of the dry season. A number of ways were tried to level out the labour demand with this

* The labour income on an enterprise represents the profit earned had no wages been charged. The costs of buildings, deadstock and general holding maintenance are not apportioned between the many individual crop accounts and appear as separate costs in the profit and loss account. The total labour income is the farmer's earnings from the whole farm having met all direct and indirect costs (excluding his own wages).

cropping but none were completely successful and none resulted in satisfactory earnings. The conclusion after four years' work was that short-term crops were unsuitable for peasant farms in this area.

Although the conclusion was clear, the reason for it, in the face of the good yields and the popularity of short-term crops with peasants, was not at first apparent. There was considerable discussion before the truth emerged. It was that the popularity of short-term crops could only be attributed to the general lack of capital and the apparent cheapness in the peasant's view of his own labour. An ordinary peasant with no money behind him can grow a crop of maize with little cash outlay and a quick cash return; by contrast a well grown crop of sugar cane involves considerable expenditure and a delay of fifteen months before any revenue is obtained. As a result maize is overplanted in relation to its profitability and well tended cane is underplanted. The first important finding of the investigation was, therefore, that there was considerable opportunity for increasing productivity on peasant farms by concentrating on capital-demanding enterprises; indeed, carried further, it has proved that the greatest investment opportunity for the peasant is not in machinery and special equipment, but in enterprises that require heavy investment and respond to detailed management. Without such assets a peasant has little chance of high earnings from his own labour.

Reorganization of the Manual Arable Farm

A careful analysis of the first four years working of the Manual Arable farm showed that the only field crops likely to be profitable were sugar cane and yams, and that these two had labour demands which could be made complementary. The characteristics of sugar cane are the relatively high labour demand in the dry season for harvesting (50 per cent of the total) because planting is necessary only once every five years, and little cultivation is required for ratoons; yams, on the other hand, demand little labour at harvesting (about 10 per cent of the total), but much for preparation and planting. Under St. Augustine conditions it has been found necessary to plant yams as early as possible and recent practice is to arrange the farming programme so that planting is completed actually before the rains start in June. The plan was, therefore, to plant and cultivate yams from June to August and plant cane in September to be harvested as over-year 15 months later. The very heavy labour demand for trenching and planting of yams was spread out by preparing the trenches on one field from which cane sets had been cut in November, preparatory to planting in the following June (*Figure 1*). It was originally intended that cane and yams should be the bare bones of the rotation and other crops would be added when they proved necessary; no additional crop of any importance has, so far, been required.

The combination of only three enterprises, cane, yams and livestock, has, in fact, proved completely sound. Not only does it allow excellent labour utilization throughout the year, but the enterprises are mutually contributory. Livestock provides pen manure for the yams, one of the few crops apart from market garden ones that responds profitably to this expensive fertilizer; cane supplies dry season fodder for livestock and trash for the yam trenches;

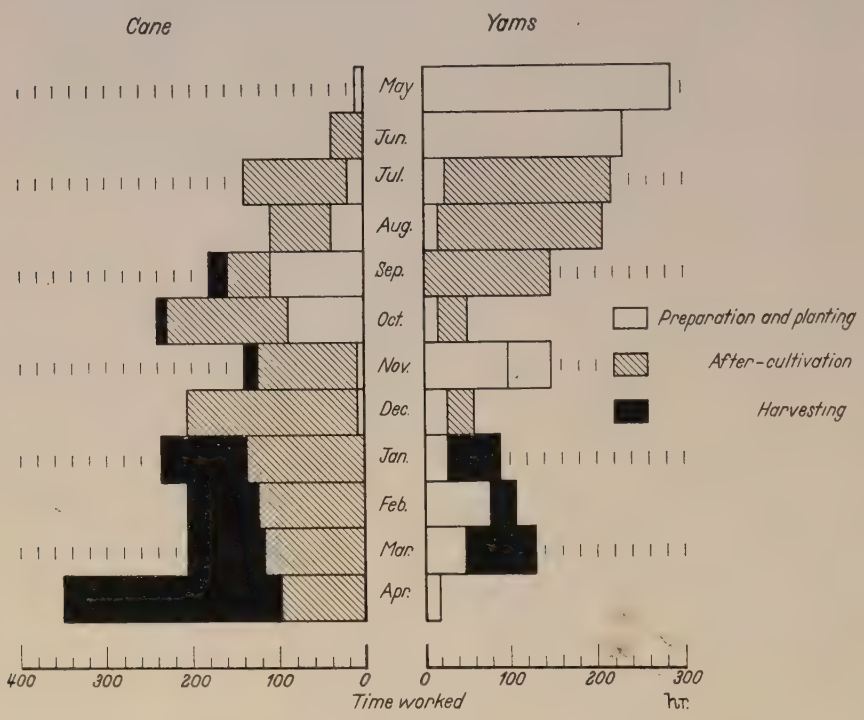

Figure 1. Monthly distribution of labour on crops (ex grass)

yams improve the fertility of the cane land by building up the organic matter content of the soil and suppressing weeds. The success of this combination indicates that careful organization of enterprises is as important on a peasant farm as on a larger one—if not more so.

As a result of this reorganization it was possible to increase the arable area of the farm from 1·6 to 2·6 acres. When, after three years, the new rotation had become fully established, the gross income had risen from $800 to $1,800, and the total labour income from $500 to $1,200 (*Table 4*).

Table 4. Manual Arable—Current Revenue and Expenditure, 1952/53

Expenditure		*Revenue**	
	$		$
1,827 lb. feed	146·16	422 gal. milk	443·00
1,343 lb. fertilizers	107·44	62½ tons cane	625·63
1,240 lb. seed	57·20	11,859 lb. yams	592·95
Supplies	19·91	65 lb. pumpkins	3·90
Services†	208·16	Final payment on	
12,195 lb. grass‡ purchased	36·58	1951/52 cane ..	199·97
Depreciation and holding maintenance	120·00		
	695·45		1,865·45

* Excludes a two-year heifer sold for $250.

† Includes cane carting and loading ($156), livestock service, rent, *etc.*

‡ Peasant's Guatemala grass (*Tripsacum laxum*) replanted during year (after 20 years); no cutting between October and February.

A total labour income of $1,200 for a man and woman working an eight-hour day on a total of only 4½ acres in Trinidad has been described as astonishing. Many local agriculturists consider it unnecessarily high, but anything lower in the writer's opinion is likely to result in a degenerative type of half-time, half-hearted farming so typical of ordinary peasants. Since 1953 the workers on this farm have employed their time to even better advantage and have become more and more forward with their programme. It is now (in 1955) proposed to attempt an extension of the arable area by another acre by incorporating another yam–cane shift. It seems quite possible that this increased arable area could be farmed at the previous high standards with no more labour or livestock. If it can, a total labour income of $1,800 a year is possible. Such an income would place the peasant in an impregnable position as a permanent self-supporting farmer in the face of any foreseeable fall in prices of his products in the future.

Arable Dairy

The arable dairy which was designed to support three milking cows was severely handicapped in the first four years by the poor quality of livestock obtainable. It has been found that the system of cutting, rather than grazing, grass (the only one possible on this intensively used land) requires a milk yield of 400 gal. per cow in order to give a labour income equal to current wages. During the first four years of this farm milk yields never reached 300 gal., and the number of livestock never reached three mature cows. During these years no less than 12 animals were brought on to the farm and three home-bred heifer calves were retained in an effort to assemble a satisfactory herd. The difficulty of obtaining suitable animals, which in itself was an important practical finding, handicapped the efficiency of arable cultivation. The original arable area of 0·8 acre was far too small, but was not expanded rapidly because it was thought that with full milk production little time would be available for crop work. As a result, excessive time was spent on the small crop area; on yam production it was 10 per cent higher than the Manual Arable, plant cane 24 per cent higher, and ratoon cane cultivation 55 per cent higher. Even so, the couple was not fully employed and in some years the woman had to be given work away from the farm for as long as three months. After the first three years it was decided that short-term crops should be discontinued and a yam cane combination tried. The combination consisted of a higher ratio of yams to cane in order to make full use of the larger supply of pen manure, and was effected by substituting Elephant grass (*Pennisetum purpureum*) for some of the cane break. The whole rotation consisted of 15 courses as follows:

(1) Elephant grass
(2) Elephant grass
(3) Elephant grass
(4) Elephant grass
(5) Yams (pen manure)
(6) Elephant grass
(7) Elephant grass
(8) Elephant grass
(9) Elephant grass
(10) Yams (pen manure)
(11) Plant cane
(12) Overyear cane
(13) 1st ratoon
(14) 2nd ratoon
(15) Yams (pen manure)

This rotation occupied $1\frac{2}{3}$ acres of land, two-thirds of which was previously in permanent Guatemala grass; the total grass area remained the same at about two acres.

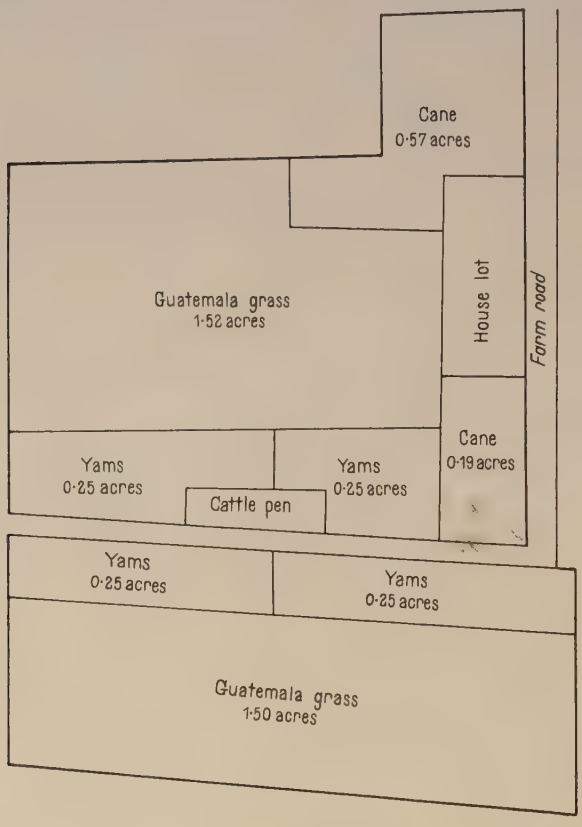

Figure 2. Arable Dairy

This rotation appeared attractive because many of those interested in the investigation had a high opinion of Elephant grass as compared with Guatemala grass. It was clear from the Specialized Dairy (see p. 268) that the handling of grass was an unrewarding and time-absorbing occupation for a dairyman, and this Arable Dairy rotation would allow the tethering of animals on pickets in those grass plots that were to be broken up for yams. The rotation of yams and grass would, it was hoped, improve grass yield and so lower the cost. These hopes were not realized, chiefly because Elephant grass proved not to possess any virtues that were not shared by Guatemala grass, and possessed some peculiar vices. The worst vice of Elephant grass on this land is that it harbours and can be devastated by froghopper (*Tomaspis varia* Fabr.). An outbreak in October 1950 reduced the production of two Elephant grass plots from 24 to 7 tons per acre for the year and provided a dangerous retreat for the pest. Because of the necessity of replanting the grass every three years, and the damage due to froghopper, the cost of Elephant grass at the pen ($8·70 per ton) proved

to be more than three times as much as Guatemala ($2·60 per ton). The farm had, therefore, to be redesigned a second time.

The new plan laid down in 1952 is shown in *Figure 2* and represents a complete change in the method of operation. By that year it was realized that cows yielding even 480 gal. (the average achieved that year) would never be big profit earners or capable of providing most of the labour income; crops would have to contribute equally and yams were pre-eminently the crop of the Arable Dairy. Everything should therefore be arranged to make yam cultivation as labour-saving as possible so that the greatest acreage could be cultivated. The yam plots, for this reason, were not rotated with the other crops and could thus remain permanently in the position that ensured the least laborious transport of grass and pen manure. Permanent Guatemala grass was planted to excess (one acre per cattle unit compared with two-thirds previously) to provide a surplus for the yam trenches in the wet season as an addition to the deficient supply of cane trash. One of the four quarter-acre yam fields was fallowed each year so that it could be trenched early, that is, in the wet season; on the other two fields trenches were dug in the process of lifting the yams. Sugar cane was retained only to provide dry season fodder and this crop was relegated to odd corners of the farm.

The test of the practicability of this plan was whether the couple could prepare and plant three-quarters of an acre of yams early enough to ensure a satisfactory crop. In 1953 the peasant was faced with this full programme and carried it through adequately; by August these yams had covered over completely and required little more attention. The plan was, in fact, practicable and it would have only taken time to prove its profitability. Unfortunately the investigation was summarily closed down in August 1953 and although it has been possible to resuscitate two of the farms, the Arable Dairy is not one of them. It is possible, therefore, only to estimate the final result (*Table 5*). With this far more efficient layout and a better

Table 5. Arable Dairy—Estimate of Current Income and Expenditure

Expenditure		*Revenue*	
	$		$
3,800 lb. feed	304	1,200 gal. milk	1,200
700 lb. fertilizers	56	15 tons cane	150
3,000 lb. yam seed	150	22,500 lb. yam	1,100
Supplies and services ..	150	3 calves	30
Depreciation and holding maintenance	200		
	860		2,480

Difference available for labour income $1,620

milking herd than in the early years, prospects of this farm appeared to be very good. The estimated surplus of $1,620 over expenditure is $400 above the minimum required and $400 greater than the present earnings of the Manual Arable. These estimates assume a herd averaging 400 gal. per cow, rather less than in the last year of operation, and if milk yields were higher

an increase in labour income of $200 could be expected for every increase of 100 gal. per cow.

Thus, by patient experimentation a suitable organization for an arable dairy was finally developed. It is noteworthy that this differs in many respects from the Manual Arable and, in fact, from any of the other types, and that success depends both on the quality of the cattle and the arrangement of crop production; this farm is not, however, one for a young man to start on; a manual arable would be much less hazardous and would provide a good base on which to build a productive herd over a period of years.

Draught Oxen

The original plan for the ox farm demonstrates the ignorance that existed in 1947 of the logistics of peasant farming. A total area of only three acres, including only 1½ for arable land, proved to be completely inadequate for the proper utilization of a pair of oxen. In the first three years the oxen worked only 450 hr. or about one month each a year and cost an average of $2·80 per animal day worked—nearly twice as much as the human labour that drove them! In these years only 12 ox hours were worked for every 100 hr. of human labour. This low ox utilization proved to be a vicious circle: the less the animals worked the less able and the less trained they were to do more work. For instance, inter-row cultivation was always assumed to be one of the functions of the oxen, but only seven days of this work was undertaken in an average year. With so little practice neither peasant nor oxen attained any degree of competence.

The discontinuation of short-term crops on this farm allowed a substantial increase in the arable area, eventually up to five acres. The rotation of cane and yams was designed to provide a smaller proportion of yams than on the other farms because it was thought that yams were not so amenable to ox work as cane. The rotation was as follows:

(1) Plant cane	(6) Plant cane
(2) Overyear cane	(7) Overyear cane
(3) 1st ratoon	(8) 1st ratoon
(4) 2nd ratoon	(9) 2nd ratoon
(5) Yams	(10) 3rd ratoon

This rotation occupied five acres and the peasant was required to plant one acre of cane and half an acre of yams each year and harvest about 3½ acres of cane. This larger area allowed the serious development of ox work which was increased in the last two years to 1,300 hr. a year or about 34 per 100 hr. of human labour. During this time every effort was made to modify the methods of crop cultivation in order to make the fullest use of ox power. For instance, cane was planted in plough furrows in the form of long stem cuttings and the rate of planting material was increased to as much as 6½ tons per acre with the object of reducing the amount of intra-row cultivation which had to be done by hand; all inter-row cultivation of both plant and ratoon canes was done by oxen. Cane trash was removed by ox-cart to the yam field and methods were being developed to windrow it with the aid of oxen to facilitate loading. The efficiency of the cane-carting which occupied about 30 per cent of the oxen's total working time

was greatly improved by the investment of some $430 in a pneumatic-tyred cart; it was expected that the cane crop would eventually increase to about 180 tons a year.

It proved gratifying, though somewhat unexpected, that the modification of cultural methods to make the best use of oxen was applied with equal success to the yam crop. Oxen were used for all the yam field preparation including the opening and closing of trenches; the yams were staked every alternate row so that the alternate furrows could be intercultivated by oxen and only one hand weeding was necessary; experiments were progressing with the use of a potato lifter to dig the yams and satisfactory results were obtained in the last year. So successful were these efforts to utilize the oxen on yam cultivation that plans to extend the farm beyond the five arable acres consisted of adding an extra half-acre of yams and converting the cropping to a six-course rotation of one-acre fields.

Table 6. Draught Oxen—Estimated Revenue and Expenditure (High Estimate)

Expenditure		*Revenue*	
	$		$
2,000 lb. feed	160·00	500 gal. milk	500·00
4,000 lb. fertilizer	320·00	180 tons cane	1,800·00
3,400 lb. yam seed	170·00	25,000 lb. yam	1,250·00
Supplies	55·00		
Services (including rent) ..	170·00		
Depreciation and holding maintenance	300·00		
	1,175·00		3,550·00

This holding, like the Arable Dairy, fell victim in 1953 to the financial guillotine and its final production cannot therefore be demonstrated. Estimates of the possible conclusion have been made on the basis of the last year's working and are presented in *Table 6*. The estimated margin of $2,400 is obviously a handsome return by Trinidad standards for a man-woman unit of labour on about eight acres of land. Of the five farms tried, the Draught Oxen farm offers the greatest opportunity for capable, hard-working peasants.

OTHER FARMS

The other two farms, Specialized Dairy and Market Garden, were intended to be complementary in respect of pen manure. It was assumed that a market gardener with only one cow would not be self-supporting in manure and would have to fill his requirements by purchases from a dairy farm. The two holdings were, however, not established simultaneously and the Market Garden was permitted to purchase any manure required during the first $2\frac{1}{2}$ years before the Dairy was established. The delay in establishing the Dairy was due to the difficulties being encountered on the arable farms in obtaining satisfactory milking cows. When the Dairy was commenced in December 1949 it was realized that a satisfactory herd could not be purchased and that one of the first questions this unit would be expected to answer was how long and how much money would be required to build up the herd.

The complementary nature of these two farms disappeared by 1950 when it was proved that the Market Garden could be self-supporting in manure.

Specialized Dairy

This farm was planned to carry as large a herd of cows as the labour unit of one man and woman could satisfactorily tend. It was expected that between six to eight milking animals would be kept and a total labour income of as much as $2,000 to $3,000 would result when 400–500 gal. cows were obtained. The farm has proved that these favourable financial results are never likely to be achieved under St. Augustine conditions; in the 2½ years of operation the accumulated deficit below wages amounted to $3,420 and if the peasant had been working on his own account nothing would have been left for his own subsistence; even then the herd had not proved itself. It was clear, in fact, that a farm of this kind would need at least $3,500 extra capital in order to finance the development of a productive herd. The reason for discontinuing the farm after 2½ years was not, however, because of its unprofitability, but because of the fodder problem and general unsuitability of the system to the particular area tried.

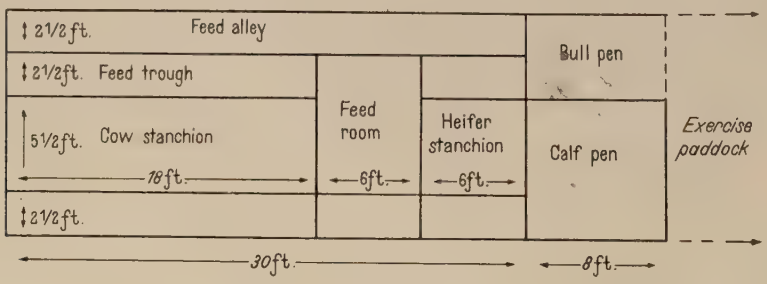

Figure 3. Floor plan—Dairy shed

It was found in the first year that the labour unit could, with difficulty, manage only six animals even though few of them were milking and not heavily at that. The poor labour utilization was due chiefly to the large quantity of grass that had to be handled when the animals were kept in a pen designed to produce large quantities of pen manure. Grass consumption was at a rather lower rate than on the arable farms, but amounted to 72 tons a year in total, all of which had to be cut and headed over 100 yds. or more of uneven ground. The 20 tons of manure that had to be cleared from the pen usually three times a year proved to be quite beyond the capability of the resident labour and had to be sold raw in the pen. Further, it was laborious to tie and milk the animals singly outside the pen and difficult to keep them clean. By April 1950, six months after the start of the farm, it became obvious that more equipment would have to be provided in order to improve the labour efficiency.

The main innovation was the building of a rustic cow byre equipped with properly guttered concrete floor. This byre was constructed of the cheapest material (round wood and thatch) and to the minimum size, but it cost $790, or about as much as the peasant's own house (*Figure 3*).

The other improvements consisted of fencing one acre of land at a cost of $165 to provide some grazing, although it was realized that the yield under St. Augustine conditions would be scanty. The farm was also equipped with a donkey and cart to facilitate the transport of grass and manure; as this manure was no longer required for the Market Garden it was used as a mulch for the grass fields. The additional tenant capital required for this equipment amounted to about $1,000.

The expensive new equipment undoubtedly improved the quality of milk produced but rather surprisingly reduced the labour requirements very little. It had been hoped that a considerable reduction in grass consumption would be effected with the controlled stall feeding possible in the byre; the donkey and cart would reduce the labour for transport; and the securing of animals in stanchions would result in quieter dispositions and greater ease of handling. The labour requirements did not fall appreciably because it was found that almost the same quantity of grass had to be cut as evidently only a small proportion was actually eaten; although the byre saved labour in some respects it increased it by requiring more frequent cleaning and more frequent transport of manure to the fields. There is no doubt that the extra equipment was necessary for clean milk production, but it did not appreciably reduce the labour requirements per cow.

The fundamental difficulty of the holding was, however, the fodder supply. In the first two years of operation there were unusually wet ' dry ' seasons and the fodder problem was one of controlling grass in the wet season. Of the original 6¼ acres, two had to be abandoned in 1950 and 1951 because the grass had not been cut regularly and had developed into a veritable jungle. The dry season of 1952 was more normal and the grass production fell off from the normal six tons a month to only 1½ tons. It was necessary in this dry season to purchase 21 tons of grass or nearly four months' supply and the farm would have required about three times the acreage to be self-supporting during this dry weather; anything in the order of 12 acres would, of course, have been quite unmanageable in the wet season.

The fodder problem had been fully anticipated before it actually occurred in 1952 and experiments away from the unit had been carried out with making silage as providing a possible solution. These experiments showed that a man and woman could not make satisfactory silage even if they were working full-time on the job, and a larger gang would have to be employed seasonally on the unit if silage was to become a feature of its management. An alternative solution was to irrigate the fodder grass area and thus maintain dry season production and reduce the total acreage required. Both these alternatives were seriously considered at the end of the 1952 farming year but both were rejected because it was apparent that other systems of farming were more satisfactory in every respect on this particular land.

If silage making with the assistance of outside labour was resorted to on the Specialized Dairy about eight acres of grass would be required for an eight-cow herd; a draught oxen holding could be established on a rather smaller acreage at three-quarters of the cost and would be expected to provide a substantially higher income to the peasant family. If the farm was equipped with irrigation about 3½ acres of grass would be adequate, but additional capital of perhaps $2,500 would be required, making a total of $10,000;

three irrigated market gardens can be established on 3½ acres for about $6,000 and their combined earnings would far exceed anything that could be expected from a single Specialized Dairy. It was concluded, therefore, that the Specialized Dairy, even when working with a satisfactory herd, would make less productive use of the land, labour and capital than alternative systems of farming. There could therefore be no justification in continuing this type of farm on this particular land. The defects revealed on the St. Augustine site indicate the conditions that would be most suitable for such a dairy farm. It should be sited on poor, low cost land that is unsuited to the production of intensive crops and should possess access to some good natural water supply. Most of the probably quite extensive farm would be devoted to grazing and a small area that could be cheaply irrigated should be planted in fodder grass to safeguard the ' greenmeat ' supply in the dry season.

Table 7. Market Garden—Profit and Loss Account, 1947/48

Losses (deficit below wages)		*Profits (surplus above wages)*	
	$		$
Tomatoes	14·91	Lettuce	76·39
Vegetables	200·76	Melongene	126·92
Livestock	53·18		
Buildings	97·00	Net loss for year ..	202·03
Tools and equipment ..	9·70		
Holding maintenance (including rent)	29·79		
	405·34		405·34

Market Garden

This unit originally consisted of one acre of crop land and one-fifth acre of Guatemala grass which, within a year, had to be increased to half an acre. In the first year a large variety of crops that are popular with local market gardeners were grown; the most important of them were lettuce, melongene and tomatoes, but in addition there were some 13 others, each of which was too small for individual costing and had to be included in one omnibus vegetable account. Only three of these ' vegetables ' produced sales of more than $10 in any month although collectively they occupied 77 per cent of the peasant's time. The first year's profit and loss account (*Table 7*) proved illuminating and laid a firm foundation for a better organized farm. It is obvious from this table that the numerous vegetable crops were hopelessly unprofitable; the reason was that the peasant could not organize his time nor could he learn the refinements for the successful cultivation of so many different crops. It was decided that the farm should be simplified by reducing the crops to lettuce, melongene, cabbage and cauliflower, and when this combination had fully proved its merit another consisting of different crops would be tried. The first year's operation showed also that one acre was a wastefully large area to cultivate in these intensive crops because every new planting required heavy preliminary cleaning of the weeds that had grown in the interim since the previous crop. Half the area was therefore put into rotational Elephant grass; the rotation was

effected by dividing the whole area into six strips, three occupied by the Elephant grass and three by the crops, each one of which occupied a whole strip for the whole year.

These modifications have during the past five years proved very sound. The irrigated Elephant grass yielding at one-and-a-half times the rate (34 tons per acre) of the arable farms provides enough bulk for one cow in a pit pen to produce 12 tons of manure a year; this allows manuring of the lettuce at a rate of 50 tons per acre, and cabbage, melongene, *etc* at about 10 tons per acre; fertilizers of course are also used. The simplified cropping has permitted the close study of the peculiarities of each crop under the conditions of this particular farm and the experience gained has resulted in large increases of both gross and net revenue (*Table 8*). The labour income in 1952/53, that is, the amount that would be available to the peasant working on his own account having allowed for all direct and indirect costs of running his farm, was about $500 more than the minimum required and is higher, in fact, than that on any other farm. Substantially, the same cropping plan has been followed in all the five years and the increase in earnings is attributable to more productive work. The cropping has not yet been changed because, even in the last year, all crops were not equally successful and not equal to best results in some previous years; there is evidently still more to be learnt about their cultivation. A year in which all crops were as successful as the best previously achieved would result in a gross income of at least $2,500 and a total labour income of $2,000.

Table 8. Market Garden Results after the First Year

Year	*Gross current revenue*	*Profit (+) Loss (−)*	*Total labour income*
	$	$	$
1948/49	816	(−) 430	400
1949/50	992*	(+) 20	906
1950/51	1,272	(−) 265	638
1951/52	1,728	(+) 397	1,462
1952/53	2,032	(+) 499	1,749

* Excluded high carry-over value of crops ($267) on the holding at the end of the financial year.

CONCLUSION

The reader who has followed this history so far may well ask where does it all lead. He may say that although the investigation is interesting as an exercise, the systems of farming evolved are not applicable to countries that do not produce sugar or have not a considerable non-agricultural population to create a market for various food products; they are not applicable to countries with different soils or seasons, or with populations which from incapacity or other causes are not in the habit of working an eight-hour day throughout the year. In fact, these farms on which so much effort has been spent apply only to the small island of Trinidad and only to certain parts of it at that.

This reasoning is quite sound as regards the farms themselves, but quite unsound when generalized to the method of investigation. These farms in their final successful form are so localized in their application precisely because it has been found necessary to exploit every local peculiarity in

order to obtain a satisfactory result. Farms in a different environment will develop on entirely different lines because they too will have to exploit the local conditions to the full. The method of developing them will, however, be essentially the same. The value of this investigation in the writer's view is the demonstration of a new tool of farm management research; the farms themselves have merely provided the material on which to use it.

This investigation has proved two important points; first, that the unit farm technique is a practical method of investigating farm management problems; and second, that there are definite economic possibilities in peasant farming. As to the first, the method has provided a wealth of factual information that has suggested, even demanded, changes in the organization of these units to improve efficiency. It has allowed these changes to be made and the results of them to be accurately observed. The success of these units has not been achieved without a struggle, but the information they have yielded could not, in the writer's opinion, have been obtained by any other means. The intensive work on what amounts to trifling areas of land has yielded handsome results.

As to the second point, the investigation has proved beyond doubt that it is possible to devise a peasant farm that will yield an income competitive with other occupations even in a relatively industrialized country like Trinidad. Earnings of up to $2,000 a year for a man-woman unit working a 48-hour week would place the peasants in a well-respected artisan class. Certain general principles have been applicable and some equally inapplicable to the sound development of all the four successful farms; in that they refer to all four, these principles may well have relevance to peasant farming in other parts of the world. The ones that proved inapplicable were the need for mechanization and for extensive co-operative organization among peasants, both rather popular panaceas of the peasant's economic ills these days. The applicable principles concern management, investment and employment.

Regarding management, these farms have shown that the application of one or a few canons of ' good farming ' does not automatically solve the problems of the peasant farm. The management and organization of the whole unit must be much more cleverly arranged so as to take the fullest advantage of the peasant's *forte* for close supervision and intelligent observation of small areas of crops and small numbers of livestock. One method is to intensify production per acre so that areas and numbers are reduced to the minimum. Another is to simplify the farms to the bare essentials required for intensive, skilful farming.

The lesson regarding capital is that the peasant farmer needs as much or more investment per acre as a large farmer, and that a large proportion will be in crops and livestock because equipment cannot be specialized for his small scale of operation; in other words, the small farm must specialize in crops and livestock that require heavy investment and respond to detailed management.

Regarding employment, these units have proved the value and feasibility of full-time employment throughout the year. Although our workers are employees, they have become fascinated by the operation of the farms

that give them regular work and a regular interest throughout the year. The independent peasant whose very livelihood depends on the success of his farm would undoubtedly become even more absorbed in a well-knit, profitable farm. Putting the same observation in a negative way, slack periods not only lower the total employment available for the year but blunt the peasant's keenness and tempt him to undertake other temporary work away from his farm. The peasant's greatest opportunity to exercise keen detailed management is completely thrown away if he becomes a part-time farmer or employs seasonal paid labour.

THE FUTURE

The investigation is at present in an atrophied state with only two units, the Manual Arable and the Market Garden, being worked. There is evidently a lack of sympathy probably due to a lack of understanding of the objects and achievements of this work so far. The main purpose of this condensation is to make the history readily available and to emphasize that these units represent a beginning rather than the end of work on peasant farming. A beginning in two respects. First, the unit farm technique is capable of being applied to a far wider set of conditions of soil, climate, topography, crops, *etc* than is represented by the College old farm. Even in Trinidad there is a far wider range in these conditions and there are many other combinations of enterprises that cry out for investigation. Outside the island there are peasants in every corner of the tropical world who suffer from as serious handicaps, and farm as inefficiently as their West Indian counterparts. The surprising lessons that have been learnt from the five little farms here reported should teach that it is foolhardy to preach any particular means of improvement in any part of the world without first testing the theory on a unit farm.

This investigation must be regarded as a beginning also because no practical use has yet been made among ordinary peasant farmers of the lessons learnt. The question has, however, been considered and proposals for applying the findings of the Market Garden unit to commercial peasant farming were put forward four years ago. For a number of reasons[3] the writer considers that at present, certainly in Trinidad and probably in most other tropical countries, well controlled land settlements will be the only practical means of propagating successful units. Such settlements will provide the means of safeguarding the capital required for improvement by enforcing the proven system of farming, thus transforming settlers from improvident labourers into stable peasant capitalists. When in any country it is generally accepted by the peasantry that they must conserve their investment and adhere steadfastly to a permanent system of farming it will be possible to disseminate the findings of unit holdings by simpler and more orthodox extension methods.

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Observations on Agricultural Development in Malaya

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It was my pleasure to serve as Agricultural Economic Officer in Malaya, attached to the American Consulate-General at Singapore, from January 1953, to August 1954. My field of observation comprised both Malaya and British Borneo, although most of my attention was confined to the former area. During this period I was able to travel extensively over the region, familiarizing myself with local crop conditions and meeting with agricultural leaders. Inasmuch as agriculture dominates the Malayan economy, progress in agricultural development was of special interest to me. Impressions gained in this all too short stay in the region are recorded briefly in the paragraphs that follow.

The basic agricultural problem of Malaya is one of imbalance. With roughly 60 per cent of total cultivated land given over to the production of rubber, the fortunes of this crop on the world market have a preponderant effect upon the local economy. This situation is coupled with the fact that Malaya produces less than 50 per cent of its rice needs and is also deficient in the production of some other important foods. This quasi-monocultural pattern afforded only limited cause for worry in the pre-war years when the impregnable role of natural rubber in world industry was taken for granted. During recent years, however, the long run outlook for natural rubber has undergone a significant change. Furthermore, the world rice shortage of the Korean period emphasized the deficiency of Malayan output. These two developments have profoundly affected local agricultural policy and have set the tone for the development now being undertaken.

Rubber replanting in Malaya often has been neglected resulting in lower yields and higher costs. The emergence of synthetic rubber as an effective competitor of the natural product has meant a more elastic demand schedule. A reduction in production costs has accordingly become a matter of major concern. The Federation Government has endeavoured to stimulate estate replanting by providing a fund out of forced savings (obtained from a cess on exports). Outright government transfer payments are being used to encourage smallholders to replant. The Rubber Research Institute is providing high-yielding planting material and is striving to improve quality through more scientific processing. This intervention of the Federation Government into the replanting programme has had reasonably encouraging results, but because of the large amount of replanting that is necessary, considerable time will be required to reach the desired goal.

It is now realized that too much dependence has been placed upon rubber as a source of national income. The Department of Agriculture is trying to

broaden the economic base by developing other cash crops. Because of the general deficiency of the soil, this is no easy undertaking. During my stay in Malaya considerable emphasis was being given to cacao. Investigations to date would seem to indicate a profitable future for this crop; however, because of the greater skill required in its cultivation, adaptation to smallholdings will necessarily involve a large amount of field extension work. Efforts to improve yields and expand acreage of other export crops such as pineapples, oil palms and coconuts are being energetically pursued. I believe that some of the upland regions of Malaya might be suitable for the production of Arabica coffee, provided research was successful in developing blight-resistant planting material.

The serious agricultural imbalance in Malaya is most in evidence with respect to the deficiency in food production. Due to the high returns from rubber and tin exports in recent years, Malaya has been able to bridge the food requirement gap through imports. The future outlook provides no assurance that adequate foreign exchange for this purpose will always be forthcoming or that foreign supplies will always be available. It is not a question of attaining self-sufficiency. Few informed persons expect that this will be accomplished in the foreseeable future. The fundamental problem is to provide for a more stable equilibrium by narrowing the gap between production and requirements. This is in essence the key to Malayan Government policy.

I was much impressed with the varied undertakings of the Malayan Government to increase food output, especially rice. An essential basis for increased rice output in Malaya is being provided through the opening up of new rice lands, improvements in water control on existing padi lands, efforts to stimulate greater usage of manures and extensive research in classifying and selecting rice seed. Department of Agriculture technicians are also conducting field investigations to determine the practicability of limited mechanization of the rice industry. Excepting certain areas where there is a regional labour shortage, mechanization seems most likely to be successful where it will either bring more land into cultivation (*e.g.* land now being used to support work animals) or will give higher yields per acre (*e.g.* the greater possibility of two crops per year). The general application of farm machinery to Malaya does not seem likely, at least until such time as the demands of urban industries drain off the excess farm labour that would result from such mechanization.

Meanwhile, buffalo and Kelantan cattle will comprise the chief capital employed in the production of rice. It would seem that improvement in the work efficiency of these animals would have an important bearing on rice yields. In some of the more important rice-producing areas of Malaya there is an acute shortage of suitable pasturage for work animals. Occasionally the local government has reserved some non-rice producing lands for grazing. Nevertheless, padi farmers, especially in Kelantan, are often compelled to board out their animals during the off season, or to sell them outright. Government research currently includes investigations with forage crops that may be found adaptable to Malayan conditions. This problem of providing suitable pasturage is also present in some of the other countries of South-east Asia. It might be that a wider exchange of

information relative to this problem would prove mutually beneficial to all countries participating.

Improved and expanded pasturage in Malaya would not only benefit farmers engaged in rice production, it would also facilitate the growth of a cattle industry as such. With its Kelantan cattle Malaya already has good basic stock for such an industry. The culling and breeding programmes of the Veterinary Department should, in the long run, bring about significant improvements in these animals. Imported Balinese and Indian cattle are important in this breeding programme. Quality improvement of buffaloes would also further the development of the local livestock industry. It has been indicated in the Philippines that cross-breeding of Indian murrah buffaloes with the indigenous carabao may afford a long-run opportunity of improving the native stock. At present the average padi farmer views his cattle only as beasts of burden. Education aimed at teaching farmers the intrinsic value of these animals would probably stimulate a more diversified agriculture.

The establishment of an adequate farm credit programme would promote the growth of a more healthy agricultural economy. It would seem to me that its adequacy should be measured by its effectiveness in meeting farmers' demands for funds, and especially short-term demands. Farmers lacking collateral might be provided with funds on a crop potential basis. This credit need today is being met largely by money-lenders who frequently charge exorbitant rates of interest. This *padi kuncha* system, as it is called in Malaya, tends to give money-lenders a significant hold over the padi farmers. The Rural and Industrial Development Authority (RIDA) has made some significant contributions, but the creation of a country-wide programme is hardly within the province of this agency. The promotion of farmers' co-operatives by the Federation Government is an important step in the right direction. The *padi kuncha* system, however, is so thoroughly entrenched in the rice-growing areas of Malaya, that a major effort is essential to its complete eradication.

A special advantage of a sound farm credit programme is that it may lessen the necessity of resorting to outright government subsidies. For instance, in order to stimulate the use of fertilizer in Kelantan in 1952, the Malayan Government agreed to pay one-half of the cost of fertilizers used by farmers. As was expected, the resulting increment in yields would have justified the use of fertilizer at full cost price. With adequate credit available to farmers it may not have been necessary to subsidize the cost.

Closely related to the farm credit programme is the improvement of local storage and marketing facilities. The Federation Government, especially through such agencies as the RIDA, is making headway in overcoming these problems. Access roads, portable rice mills and co-operative storage facilities are some of the important contributions being made. Through its system of self-help the RIDA is promoting an important form of domestic capital formation.

Because of the significant accomplishments in agricultural research, an increasing emphasis upon extension would seem to be in order. Achievements in rice seed classification and selection not only promise higher yields, but also afford the possibility of two crops a year in some localities through

the use of shorter term varieties. Teaching farmers better cultural methods in using this seed will permit research to have its maximum effect upon output. The State agricultural officers are basic to successful extension, but with limited staffs they are restricted in the amount that they can undertake.

One of the main difficulties in connection with the expansion of adult agricultural education stems from the shortage of locally trained technicians. The small agricultural school at Serdang turns out only a handful of technicians each year and the scope of the training is limited. When I left Malaya last August the establishment of an agricultural college was under consideration and it is to be hoped that it is only a question of time until it is in operation. Such a college could engender a local agricultural service of prestige by maintaining high standards and granting degrees, thereby attracting the more capable farm youths. Its curriculum would be more attuned to the needs of Malaya than would a foreign college. The Philippine Agricultural College at Los Baños is a good example of the beneficial effects of such an institution. With an enrolment of more than 1,000 students, this college is providing an increasing number of trained technicians and research specialists to meet both public and private needs.

In this article I have chosen to give special emphasis to those longer-run problems which are likely to come up for increasing local consideration in the future. Consequently, I have not attempted to review the many other accomplishments of the Department of Agriculture and related agencies. This omission should not be construed as a failure to recognize the overwhelming importance of these accomplishments. In its field agricultural officers, Malaya has the services of a group of capable agronomists whose selfless interest in improving Malayan agriculture will become increasingly apparent in the future.

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The Position of Cattle in India

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IMPORTANCE OF CATTLE IN INDIAN AGRICULTURE

Cattle are an essential factor in India's agricultural economy. All agricultural operations involve the use of cattle either as motive power for ploughing and irrigation or for threshing the harvest and carrying it to the distant markets. They also provide organic manure which is the main source of farmyard manure in India. In many parts of the world, cattle are valued primarily for food and milk, but in India their value is mainly determined by their use for agricultural operations. The vast area of the country and the wide range of physical and climatological conditions that obtain in the different regions, naturally led to the development of the wide variety of cattle that are found in the country. The cattle and buffalo population in India is abnormally high, amounting to over 60 per cent of the human population. The latest estimate places it at about 136·372 million cattle and 40·618 million buffaloes. For draught purposes oxen are mainly used everywhere, though buffaloes are important as draught animals in the rice tracts and wetter parts of the country. The buffalo is important as a dairy animal, as its milk yield is higher and the percentage of butterfat content is larger than that of the cow.

SOME IMPORTANT BREEDS OF CATTLE AND BUFFALO

The efficiency and capacity of these animals also vary considerably in different regions depending upon the breed and other factors that govern their existence. The Indian Council of Agricultural Research recognizes 31 breeds of Zebu and eight breeds of buffalo. A few of the breeds of Zebu are generally called milk breeds as distinct from those which not only produce milk in large quantities, but are well known for their draught qualities. The following are well known draught cattle: Hissar (Punjab); Kherigarh and Powar (Uttar Pradesh); Nagore (Rajputana); Malwi (Madhya-Bharat); Goalao (Madhya-Pradesh); Nimar (Madhya-Bharat, Madhya-Pradesh and Bombay); Khillar, Krishna Valley Breed and Dangi (Bombay); Ongole and Kangayam (Madras); Hallikar and Amrit Mahal (Mysore). The best milch cattle are the Sindhi and Sahiwal which are now largely found in West Pakistan, but small herds exist in some parts of the country. The best among the dual-purpose cattle are the Hariana (Punjab); Gir (Saurashtra and Bombay); Kankrej (Bombay); and Tarparkar (Kutch).

Equally important to the dairy industry are the buffaloes found in different parts of the country. The domestic buffalo can be divided into the river and the swamp types. Those found in India are largely of the river type. The following are some of the important breeds of buffalo: Nili and Ravi (Punjab); Kundhi (Sindh); Murrah (Punjab and Delhi);

Jaffarabadi (Kathiawar); Mehsana (Baroda State); Surti (Gujerat, Baroda State and Deccan); Nagpuri (found in Central and South India); Parlakimidi (Parlakimidi estate of Orissa); and Toda—a hill breed (plateau of the Nilgiri Hills, Madras State).

THE PROBLEM OF EXCESS CATTLE

As already stated, the unduly large cattle population acts as a drag on the country's economy, since a large number of them are useless and decrepit, being undersized and underfed. In other countries such cattle would not be maintained, but in India the disposal of these cattle has become difficult due to the peculiar social customs and religious sentiments. Hence, the number of cattle has increased rapidly which has led to deterioration in their quality still further. The strong feelings of the people in this matter are reflected by the agitation that is being carried on at present in various parts of the country against cow-slaughter. The object of the anti-cow-slaughter movement is to secure total prohibition of slaughtering these animals; in fact, an unofficial bill is going to be moved in the Indian Parliament for the total ban of cow-slaughter in the country. Such a prohibition already exists in Madhya-Pradesh and in Mysore State. So, the solution for the excess cattle population has become more difficult in the country. If the problem is strictly viewed from the economic angle, it will be evident that it is easier to pursue a policy of cattle improvement, if it is co-ordinated with a scheme of eliminating undesirable cattle, especially those afflicted with diseases like tuberculosis *etc.* It is a fallacy to think that India needs every cow for producing manure, for the elimination of undesirable cattle will conserve fodder and other resources and greater attention can be bestowed on the better type of cattle.

The Attempted Solution

As facts stand at present, even the Government is not prepared to pursue a policy of slaughtering uneconomic cattle. Furthermore, a very large section of the people are ' born vegetarians ' who have sentimental objections to slaughter, and this fact rules out the possibility of developing a beef industry on the western model. Since slaughtering the uneconomic cattle is repugnant in this country, other methods of dealing with the problem are being attempted. Institutions like ' Gaushalas ' and ' Pinjarapoles ' are set up in different parts of the country to look after such animals, in addition to the more important work of maintaining useful cattle. It is estimated that there are at present about 3,000 Gaushalas in India with a population of over 600,000 head of cattle which are being maintained at a cost of over 30 million rupees per annum. Their object is to arrest the deterioration of the cow and to protect it from indiscriminate slaughter. It is felt that if these places are organized on proper lines they may also serve as milk-producing and cattle breeding centres. Prof. Bhansali, an ardent social worker, started a movement in 1952 called ' Go-dan Yagna ' (Cow Gift Movement). Cows that are donated in this movement will be distributed among local people on condition that they must not sell the animals or their milk. This movement is yet another indication to show the sentiments of the people. There are also certain legislative enactments for the

protection of cattle like the ' Madras Animals and Birds Sacrifices Prohibition Act, 1950 ' and ' The Prevention of Cruelty to Animals Act '.

Animals Slaughtered Mainly for Hides

At present about 5·27 million cattle and about 1·33 million buffaloes are annually slaughtered in the various states in India. Many of these animals are slaughtered mainly for their hides. In fact, India is regarded as a surplus area in respect of its resources of raw hides and skins. Normally, it produces about 16·2 million cattle hides and about 5·5 million buffalo hides a year, the bulk of which is derived from animals that die a natural death. Hence, the output of hides increases when famine, flood and cattle epidemics *etc*, afflict the country.

It is felt that any improvement in the rural economy of the country must necessarily depend upon improvement in the quality of its cattle, since cattle are indispensable for draught purposes. This fact is clearly kept in view by the Government in the various schemes that they have launched to improve agriculture and animal husbandry in the country. It is significant to note that Indian cattle contribute about 40 per cent of the total national income even though they are not properly organized and developed.

POSITION OF THE DAIRY INDUSTRY

The total production of milk in India is about 745 million maunds and to this may be added 250,000 maunds of milk equivalent, which represents the excess of imports over exports. Of this, 516 million maunds are marketed while 113 million maunds are retained by the producer for his consumption and the balance is fed to calves. So the milk or milk products available for human consumption in India work out to an average of 5·8 ounces per head per day. This is less than one-third of the requirement according to minimum nutritional standards. Apart from the very low daily per capita consumption of milk in India, it is very unevenly distributed. The distribution is determined by the income of the people. The poorer classes cannot afford to take milk or ghee every day and so they consume it on festive occasions only. Hence, in addition to increasing the supply of milk, it must be more evenly distributed among the people. It will be of interest to note that 49·1 per cent of the total milk produced in India is supplied by Zebus, while 47·5 per cent is provided by buffaloes, and the balance of 3·4 per cent is contributed by goats. Nearly 95 per cent of the milk-producing animals are maintained in the rural parts of India, and it is common for an individual to own a few animals. Large dairy farms are generally located near cities and towns. Out of the total milk production, about 28 per cent is consumed as liquid milk while the rest is converted into milk products. The most important milk product is ghee (clarified butter), and nearly 57 per cent of the total milk is converted into this. Since ghee is clarified butter from which practically all moisture has been driven off, it keeps well for long periods even under tropical conditions of storage and ordinary packing. It is found that well-made ghee can remain good for about two years and can be reconditioned by clarification. This accounts for its extensive manufacture.

But it is regrettable to note that the quality of market milk is generally poor, due to ignorance regarding the proper methods of handling milk,

improper sanitation of the utensils, the lack of refrigeration and the practice of adulteration. So far, milk recording is confined largely to Government and other organized herds maintained on big farms. Only 0·03 per cent of the cattle are being recorded at present. The various Government farms maintain regular records which are highly useful, but the information available regarding the cost of producing milk in other organized herds in India is very limited and practically no data exist regarding the production of milk under village conditions.

Distribution of Milk

Many types of organization exist for marketing milk in the country. The small private dairy, which generally maintains a milk plant, collects milk and then distributes it, after converting a part into dairy products before it is sold. The large private dairies not only supply pasteurized milk in bottles by house-to-house delivery, but also manufacture butter, cheese, *etc*, and distribute these through various branch dairies located in different cities. Of the Government dairies, the largest organizations are the military dairies which maintain large herds and distribute milk and its products to the military personnel. The other Government-owned dairies are connected with educational institutions or experimental stations. Generally, they handle only the milk produced in their own herd which is supplied to hostels, hospitals and private customers by wholesale or retail distribution. Most of the co-operative dairies primarily supply milk, and milk products are manufactured as a means of disposing of surplus milk. There are three types of co-operative dairy organization: (1) the consumers' co-operatives which, though few in number, supply quality milk and milk products to their members; (2) the distributors' co-operative, the main object of which is to improve the welfare of the distributors by supplying the customer more promptly and regularly with milk of a better quality; and (3) the producers' co-operatives, the highly successful organizations which collect milk and distribute either in bottles or bulk, any surplus being converted into milk products and sold.

CATTLE AS MOTIVE POWER

Equally important to the national economy is the contribution made by cattle labour. According to Dr. Wright, a conservative estimate of the cost of cattle labour in the country amounts to Rs 4,000 million. The capital invested in road transport in India is about Rs 12,000 million, out of which the bullock carts account for about Rs 6,700 million. While railways with an investment of Rs 8,380 million carry 95 million tons of goods, the bullock carts, numbering about 8,400,000 carry more than 100 million tons of goods over difficult pathways which are inaccessible or uneconomic to motor transport. Nearly seven million people earn their livelihood as drivers, wheelwrights, *etc*. The number of bullocks gainfully engaged during the farming season is about 17 million, while nearly five million animals work throughout the year. Of the 250 million people who depend on agriculture for their sustenance about 80 million labour in the field and farm with the help of the cattle. Probably, it will take a very long time for mechanization to take the place of draught animals and in the meantime it is better to conserve the experience of the ages by effecting improvements in the shape

of the cart, its wheels and rims, and the plough-shares used in cultivation. As the bullock is the primary source of animal power in the country, improvement of agricultural tillage will rest largely upon the quality of bullocks. To improve their quality India requires about a million stud-bulls, while the number available at present is only about 10,000. The Government has a plan for opening 1,600 centres in different parts of the country where first-class stud-bulls would be made available for breeding purposes.

Importance of Farmyard Manure

In addition to the main contributions of milk and labour by the cattle, they are the main source for supplying manure for cultivation. Due to the ignorance, conservatism and poverty of the Indian agriculturist, fertilizers are not used to the same degree as in advanced countries. Even in cases where fertilizers are used, they are considered more as a supplement to, than a substitute for, farmyard manure. The farmyard manure consists of cattle dung, urine, fodder refuse, crop residues, supplemented by green manuring, folding of sheep and goats, *etc.* Generally, it is collected in baskets every day and emptied in the manure pit and well pressed. Later, it is taken out to the field and is spread before the beginning of the monsoon and worked into the soil by harrow or plough. It is considered as an unrivalled restorative for depleted soils, since it adds humus to the soil and provides it with the capacity to absorb and retain moisture. Further, it brings warmth to the soil by the chemical and bacterial decomposition of the straw. Hence, farmyard manure is considered as an invaluable fertilizer, especially, in an old agricultural country like India. Unfortunately, due to the ignorance of the cultivator and the relatively high cost of alternative sources of fuel, a large quantity of cattle dung is used up as fuel, while indifferent handling and improper preservation methods result in poor quality manure. The cattle urine is also neglected and wasted. Notwithstanding these defects, the annual value of cattle manure has been estimated at about Rs 2,700 million. With more efficient collection, preservation and economic utilization the value of cattle manure could be substantially increased.

VALUE OF CATTLE HIDES

The next important by-product of cattle industry in India is the hides and skins. Their annual value is placed at about Rs 400 million. India holds the first place among producers of cattle hides; nearly 75 per cent are now locally tanned, and the balance exported in the raw condition. But quality is not always uniform due to faulty methods of flaying and the practice of mixing hides of dead and slaughtered animals together. In recent times, serious efforts are being made to improve their quality. Flaying methods are being improved and an inducement is offered to all flayers of A and B grade hides in the form of a small premium out of a fund built up from voluntary contributions made by the tanners and shippers. Cattle hides are cured for the export trade by air-drying and dry salting. Air-dried hides are treated with a solution of arsenic to ward off insect damage before they are exported. The Agricultural Marketing Advisor to the Government of India has attempted to grade slaughtered cattle hides. Hide-grading

stations were started at slaughter houses at Delhi, Agra, Bandra (Bombay), Bareilly and Rampur and specifications for grades were formulated. Hides and skins were included in the schedule to the Agricultural Produce (Marketing and Grading) Act of 1937. This should provide sufficient incentive to secure a steady improvement in the quality of hides produced in India.

Growth of Tanning Industry

India has developed a valuable tanning industry. This industry has developed to a remarkable degree since World War II. At present, it has the capacity to tan all the buffalo hides and nearly all the ox hides and sheep skins. Tanning in India can be broadly classified into two types, indigenous and modern. The finished products, tanned according to the indigenous method, differ a great deal and can be classified into four broad groups. The first three varieties are all consumed in India, while better grades of the fourth variety, half-tanned leather, are exported to foreign markets. The half-tanned cattle hides and calf skins are known in the international trade as ' East India Tanned Kips and Calf Skins '. Chrome tanning has also shown phenomenal development. A large number of tanneries have grown up. Some of these tanneries are quite big and equipped with the latest chrome tanning machinery. A few training centres in tanning have been opened and maintained by the various states in India. There are also peripatetic tanning demonstration parties under the Industries Department of the Governments of West Bengal, Uttar Pradesh, Bihar and Orissa which hold instructional classes in rural areas in order to introduce improved processes of tanning. To look after the interests of the Indian tanning industry a Tanners' Federation was started a few years ago. Its headquarters are located at the Upper India Chamber of Commerce, Kanpur. Most of the organized tanneries in India are members of this federation. At a very rough estimate the capital invested in the leather industry can be placed at about Rs 200 million. Compared with the leather industries of Europe and the United States of America, the Indian leather industry is still unorganized and inadequately developed. This industry still depends on foreign countries for some of its machinery, chemicals and other materials. Until these ancillary industries are developed in the country, the Indian leather industry will be handicapped when compared with the leather industry of Europe and America.

BY-PRODUCTS OF CATTLE

Other important by-products of the cattle industry are the bones, blood, horns, tips, *etc.* Unfortunately, there are no reliable statistics about the total annual output of the products. A fairly large percentage of the total annual output appears to be wasted, while the methods of collection, preservation and utilization of these products continues to be very defective. It is significant to note that only a fraction of the total output is exported. There appears to be considerable scope for co-operation in the proper use of these valuable products which can be recovered from dead and slaughtered animals. The disposal of dead animals is at present done by the most backward classes of the community. Their organization into co-operative societies will serve the double purpose of improving the standard of living

of these classes and of making available to the country valuable by-products of these animals.

THE BASIS OF IMPROVEMENT OF CATTLE

To improve the quality of the Indian cattle, it is essential to have a comprehensive scheme covering every aspect of animal husbandry in the country. Any scheme of livestock improvement will necessarily take a long time when we consider the extent and complexity of the problem. It is essential to decide first the type of improvement desired in the animal. In most countries of the world, cattle are maintained mainly for milk and meat, whereas in India they are primarily used as draught animals for the plough or the cart. In India, a dual purpose animal is one in which the females are good milkers and the males are powerful draught animals.

Further, it must be borne in mind that any type of improvement contemplated will have certain limiting factors, such as climatic, economic and religious, within which the scheme has to be developed. The climatic factor is expressed in the development of distinct breeds in different parts of the world. A number of breeds of both cattle and buffaloes have been developed in the various parts of India. Good breeds of cattle are confined to comparatively dry areas of the country, such as the Hariana found in the Punjab, Central India and a few other tracts. Conversely, we find that in tracts with a humid climate, subject to heavy rainfall, or tracts which are provided with ample irrigation facilities, poor types of cattle are found. Unlike cows, buffaloes thrive best in the areas of moderate to heavy rainfall, as they require plenty of water for their daily bath. They are dual purpose animals useful both for milking and draught.

Again, the economic position of the country and the status and knowledge of the farmer and herdsman determine to a large extent the attention that will be bestowed by them on improving their animals. Professional cattle breeders existed in India for many centuries pursuing their traditional methods of selecting and rearing cattle, but they have practically disappeared from the country owing to the extension of irrigation and the consequent lack of common grazing grounds in many of the states. Further, unlike in the western countries, in India the bigger landlords have hardly attempted to raise good breeds of cattle. Hence, the burden of improving the cattle falls on the Government of India and the various state governments. Governments are making serious attempts in this direction and there are a number of Government cattle farms where pedigree bulls are reared, and these are sold to private bodies and individuals in the villages.

The injunctions of religion, especially in some of the Asiatic countries like India, have an important bearing on the attitude adopted by the people towards cattle. The present poor quality of Indian cattle is due to malnutrition, promiscuous mating, improper and insufficient care, the ignorance and lethargy of the people and the lack of a proper breeding policy. For instance, there are a number of villages, where no breeding bulls are to be found and the cultivator has to travel seven or eight miles to take advantage of a good stud-bull. Also, the methods of scientific breeding are little known to the average cultivator, and cattle are hardly enclosed, with the result that good and healthy cattle are allowed to mix with weak and

degenerate types, which naturally leads to a steady deterioration. A good breeding policy must be based on the following factors: (1) capacity for adaptation by the breed to the environment should determine the choice of breed; (2) the registration of breeding stock—both sire and dam—would facilitate identification and study; (3) records of milk yield could be used for selecting the best animals. Some records concerning the above are maintained in some of the farms in India, but the data collected will have to be more comprehensive and this requires proper analysis, while it is dangerous to make sweeping generalizations from these statistics. The next point in a sound breeding policy is testing the progeny of the bull for milk yield and the production of good heifers, and lastly, the selection of desirable characteristics in the animal, such as early maturity, longevity, docility and fertility with due emphasis on regularity in breeding, longer in-calf yield which means a greater milk-yielding period, and higher milk yield.

Necessity for a Sound Breeding Policy

A judicious selection for mating will greatly aid the breeders in producing superior stock. By such a selection, the best ones are retained for propagation and the undesirable ones are rejected both in the male and the female. In any group of animals there are bound to be some inferior ones and these should be avoided for breeding purposes. In a breeding policy castration is a negative method, while artificial insemination and natural serving by good stud-bulls are positive methods. Castration should be resorted to wherever necessary. In selecting the breed the main considerations should be the availability of the breed and its popularity in the area in which it is to be maintained, the capacity of the breed to produce milk and butter fat at a low cost, the ability of the breed to withstand the local climate, pests and diseases, and its vigour as a draught animal. Various methods of breeding are followed for transmitting the desirable qualities to the offspring. In India, as the result of crossing Indian pure-breds with European pure-breds, the first half-breds showed remarkable milking qualities. But, these could not be preserved by any combination which increased the blood of either of the parents, or by in-breeding. So, the ultimate result was disappointing. Emphasizing this point, Sir Arthur Olver states that within a reasonable period of time, it is possible, with scientific breeding, control and management, to build up from indigenous breeds, high-yielding strains which can compare favourably with European cross-bred cattle, and it is very clear that this is the proper policy to pursue under existing conditions.

Next to cross-breeding is the process of grading-up of cattle. Grading-up has begun in India and the results have been encouraging. By careful use of a proper breed of bull, much can be done by way of grading up the non-descripts distributed throughout India. As the pedigree bulls are limited in number, it will be advantageous to provide a large number of approved bulls bred under village conditions. The cost of their rearing will be negligible, while their purchase by the Government for distribution will provide direct encouragement to progressive breeders. Due to this acute shortage of pedigree bulls, it is desirable to make the utmost use of the available bulls by adopting the method of artificial insemination. The

Government of India, by introducing the ' Key Village Scheme ', aims to popularize this method for improving the cattle of the country.

Fodder Deficiency

In India the inefficiency of cattle is largely due to under-nourishment and semi-starvation. As stall-feeding is rare, the majority of the cattle have to depend on grazing, and the grasslands in the country are overstocked. Furthermore, the period of grazing is confined to about five months in the year and the cattle suffer from acute shortage of fodder during the remaining months when they face semi-starvation. Again, the extension of cultivation has reduced the available grazing land, while forests, as a source of fodder supply, are of limited value due to the stringency of the forest laws and the policy of enclosure. As the storage of fodder is quite limited, the ration of the cattle becomes precarious if the monsoon is delayed even by a short period. In a year of famine, cattle die by thousands while the survivors become inefficient workers for a long time. Definite information is lacking regarding the total quantity of fodder available in the country. On a rough estimate the fodder requirement can be placed at about 500 million tons, while the actual supply is much less than half this figure. More attention has to be paid to cultivating fodder-crops on a large scale. Conservation and better use of available fodder is equally important. As the available supplies of concentrates are very limited, there is an urgent necessity for developing the oil-crushing industry in the country which will increase the supply of concentrates to the required level.

Cattle Diseases and Veterinary Aid

Diseases are in no small measure responsible for the deterioration of cattle in India. They exact a heavy toll and cause permanent damage to the cattle which survive the attack. The incidence is greater in India because cattle diseases are not diagnosed and treated the moment the animal is attacked, which is partly due to the poverty and conservatism of the cultivator and partly due to lack of adequate veterinary facilities in the countryside.

The main diseases that affect animals in India are glanders and surra in equines, rinderpest, foot-and-mouth disease, haemorrhagic septicaemia, black-quarter and anthrax in ruminants, while tuberculosis, Johne's disease and contagious abortion are assuming greater importance than in the past. Glanders and surra are both scheduled diseases under the Glanders and Farcy Act. Surra also affects camels, cattle and dogs and in recent years its importance as a bovine disease has been more widely recognized. Of the diseases of ruminants mentioned above, all, with the exception of foot-and-mouth disease, can now be controlled either by means of sera or by vaccines. A scheme for the mass eradication of rinderpest is now under the consideration of the Government of India. India is protected from foreign infection by the application of the Livestock Importation Act at all ports at which the landing of animals is permitted.

The control of contagious diseases of livestock is carried out by the civil veterinary departments in the states. The main functions of the departments are the treatment of sick animals; prevention of the outbreak of cattle

epidemics; and general improvement of livestock. The veterinary institutions are for the most part maintained by local boards with financial assistance from the Government, and the professional staff are usually provided by the Government. But, in recent times, in many of the states the veterinary dispensaries have been taken over by the Government. The personnel of these departments are recruited from among the graduates of the veterinary colleges of which there are nine in India, one each at Gauhati, Patna, Calcutta, Bombay, Mathura (U.P.), Hyderabad (Deccan), Madras, Hissar and Jabalpur. Most of the Indian universities provide training up to graduate standard as against licentiate training which they used to give formerly.

The chief research centre is the Indian Veterinary Research Institute at Mukteswar in Uttar Pradesh and its branch at Izatnagar, near Bareilly. This institute is maintained by the Government of India and has recently been considerably expanded. It also manufactures large quantities of sera and vaccines for the use of the State departments. Serum institutes have also been opened in various states such as Bombay, Uttar Pradesh, Hyderabad and Madras. A certain amount of research is also conducted at the State colleges.

The Animal Husbandry Department of the Government of Madras attends to the main functions of veterinary service—better breeding and treatment of diseases. The Government's policy is to open veterinary institutes only in places where they are required most. The ultimate aim is to have one such institution for every *taluk*. The Madras Livestock Improvement Act (1940) provides for the castration of scrub bulls. This act has been applied to a few *taluks*. The Government have provided four mobile veterinary units with special staff so that these units can move to the outbreak spot quickly and conduct inoculations. A definite improvement in the death rate of animals has been noticed since the introduction of this scheme. The spread of cattle diseases is also checked by extending the provisions of the Madras Cattle-Diseases Act and the Madras Rinderpest Act to the affected areas. The Veterinary Biological and Research Institute located at Ranipet supplies almost the entire amount of sera and vaccines required for the State.

Many schemes are under way for the improvement of livestock in Madras State. Under the ' Village Livestock Improvement Scheme ', all scrub bulls are castrated in selected villages and breeding is done only from pedigree bulls. The ryots are paid a subsidy to retain the heifer calves. Breeding bulls are stationed in veterinary institutions. District boards are offered contributions to purchase and distribute bulls. Under the ' Premium Scheme ', premiums are paid by the Government for the maintenance of approved breeding bulls by private persons. Breeding bulls are also purchased by the Government and distributed to ryots under the ' Livestock Bull Distribution Scheme '. The Key Farm Village Scheme for improvement of cattle, with equipment and personnel for artificial insemination, has been introduced at each of the seven cattle farms in the State, and this scheme is working quite satisfactorily. Thus, it is the aim of the Government to provide as many quality breeding bulls as possible, for improving cattle in the State.

Help Rendered by the Government

Most of the states have appointed dairy development officers to organize dairying both on co-operative lines and through private enterprise. Research in dairying is done at the Indian Dairy Research Institute at Bangalore. This Institute also runs courses in Animal Husbandry and Dairying. The Union Government proposes to expand the activities of this Institute by making it serve as a central artificial insemination station for the whole of India and as a regional nutrition centre for the South Indian States. In addition to this, another institute—The National Dairy Research Institute—is going to be located at Karnal (East Punjab). The Government of Bombay has established a very large milk colony at Aarey near Bombay, where about 15,000 animals are housed under the most modern conditions. Milk is supplied to Bombay City after pasteurization. Milk supply schemes are also operating in various states.

Under the first Five-Year Plan the Government of India has allotted a sum of Rs 223 million for improving dairying and veterinary services in the country. One hundred and sixty *Gosadans* are to be opened in areas where there are grazing facilities at a cost of Rs 10 million for maintaining cattle. To improve the stock, 600 centres are to be started under the ' Key Village Scheme '. Breeding will be confined to three or four superior bulls of known pedigree, and inferior bulls will be removed or castrated. Each centre will comprise three or four villages having about 500 cows of over three years of age. The number of veterinary hospitals will be increased from 2,000 in 1951 to 2,600 in 1956. Suitable steps will also be taken to increase fodder supply.

In order to develop sound rural communities, a number of community projects have been started in the country. It is proposed that by the year 1956 the Community Development Projects (also called the National Extension Service) should cover one-fourth of the country's villages. This means the initiation of work on 1,200 community development blocks. The majority of the development blocks are under the Community Projects Administration and the rest of the blocks and the training centres for the staff are under the Ministry of Food and Agriculture. The second part of India's over-all community development programme is that which is to be supervised by the Ministry of Food and Agriculture, with financial aid from the Ford Foundation. It is expected that, in four years, a community development programme following the general lines can bring about an increase in food production of roughly 50 per cent. Among the trained technical personnel in the project area there will be agricultural extension supervisors and veterinary surgeons.

In order to improve animal husbandry the Government of Madras has formulated a five-year plan for the Veterinary Department with a total expenditure of nearly 10 million rupees. Also, the Madras Livestock Plan has been introduced to improve the bovine population of the State. The Government has a three-year plan for increasing the supply of milk in urban and semi-urban areas. Co-operative cattle breeding societies are encouraged and in 1950 there were 32 such societies in the State, in addition to 36 milk supply unions and 535 milk supply societies.

It is clear from what has been stated above, that the Government has been taking much interest in the improvement of livestock. But still there is a great deal to be done and probably in the next five-year plan, substantial provision will be made for extending these services to such an extent, that no village will be left uncovered by veterinary facilities. When this happens, probably the time will be ripe to introduce a scheme of cattle insurance to protect the cattle wealth and thereby the rural prosperity of the country.

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The Origin and Operation of The Cyclone and Drought Insurance Fund, Mauritius

From the Office of the Cyclone and Drought Insurance Board, Port Louis, Mauritius

The proposal to establish a scheme of insurance against cyclones was first put forward in 1906 by the Secretary of State for the Colonies; the details of the scheme were left for discussion, but it was made clear that the liability of the underwriters would be limited to 75 per cent of the damage. The proposal was not agreed to and since that date several other proposals have been put forward but all have shared the same fate. The stumbling block to agreement was the difficulty of arriving at a method of assessing cyclonic damage which would be acceptable to both the insurer and the insured. Among the proposals put forward with a view to solving this difficulty was one based on certain mathematical formulae which took into account the pressure and direction of the wind and the time of the year when the cyclone occurred.

Following on the disastrous cyclones of 1944 and 1945, the cumulative effect of which was to destroy the equivalent of nearly one complete year's crop, and the representations made in London by the representative of the Mauritius Chamber of Agriculture, His Majesty's Government agreed to help the Sugar Industry by a loan of £800,000 and a grant of £500,000 during the financial year 1945/46, subject to steps being taken by the local government for the establishment of an insurance scheme for sugar production. Agreement was at last reached after consultation and discussions with the Mauritius Chamber of Agriculture, and an insurance scheme against cyclones and drought was established by the enactment of Ordinance No. 53 of 1946, which came into operation on 5 October 1946. The scheme is compulsory and all millers, estates with factories and planters are bound to contribute thereto.

The Ordinance provides for the creation of a fund known as 'The Cyclone and Drought Insurance Fund' which is administered and controlled by a board known as 'The Cyclone and Drought Insurance Board', the expenses of administering and controlling the Fund being defrayed out of the assets of the Fund.

The Board consists of (*a*) three official members appointed by the Governor, *viz*: the Financial Secretary who is the Chairman, the Director of Agriculture and the Director of Statistics; and (*b*) three unofficial members, one representing the millers, one the planters, and the third the small planters.

Any member may at any time be removed from the Board and replaced by another member.

The Board may sue and be sued in its corporate name and may for all intents and purposes be described by that name.

Among other functions, the Board has to advise the Governor whether any particular year in which a cyclone or drought has occurred should be

declared a cyclone or drought year, as the case may be. This is a most important function as no compensation is payable in any year which has not been declared to be a cyclone or drought year. The declaration may be restricted to such regions within the factory area as may be specified in the Proclamation.

In order to ensure that plantations are not neglected after the occurrence of a cyclone or drought, provision is made in the law for inspections to be carried out. If an inspection reveals that the cultivation and maintenance of a sugar plantation has been neglected after the occurrence of a cyclone or drought, no claim for compensation by the owner or owners of such plantations is admissible. All plantations are not inspected, since this would not be practicable, but arrangements are made for the inspection of each estate with factory and two other plantations within the factory area.

Persons aggrieved by the refusal of the Board to grant them compensation have a right of appeal to the Supreme Court, whose decision shall be final.

The Assets of the Fund consist of:

(*i*) a sum equivalent to 70 per cent of the amount credited every year to a fund, known as 'The General Cyclone and Drought Reserve Fund' and established under Ordinance No. 35 of 1949;

(*ii*) an annual premium determined in the manner provided in the following paragraph and defrayed by every estate with factory, miller or planter, which the Mauritius Sugar Syndicate, a body corporate grouping all the millers and planters of the Colony, pays every year on or before the 31st of December to the Fund, on request made by the Board;

(*iii*) interest accruing from the investment of the amounts mentioned in (*i*) and (*ii*) above.

CALCULATION OF PREMIUM

The annual premium mentioned in sub-paragraph (*ii*) above is an amount equal to 6 per cent of the value of the average quantity of sugar which accrues to the estate with factory, miller or planter, as the case may be, during the three normal years immediately preceding, after deduction of the following expenses, *viz*:

(*a*) in the case of an estate with factory, the cost of bags and of transport of all the sugar manufactured by the factory to the docks in Port Louis, as well as the cost of cutting, loading and transporting the total tonnage of the estate's own canes, calculated by reference to the basic extraction;

(*b*) in the case of a miller, the cost of bags and of transport of all the sugar manufactured by him to the docks in Port Louis; and

(*c*) in the case of a planter, the cost of cutting, loading and transporting the total tonnage of sugar canes produced by him calculated by reference to the basic extraction.

The reason for this method of computing the premium is that, in case of a cyclone or drought the sugar producer receives compensation in respect

of the value of the sugar short produced, *excluding* the cost of bagging and transporting such sugar and that of transporting the corresponding tonnage of canes, both of which have not, in fact, been incurred. It follows that since he receives no compensation for these costs, he should pay no premium in respect thereof.

The premium, fixed at the inception of the Fund at 4½ per cent, was based on statistics from 1857 to 1945 and on estimated losses sustained through cyclones and droughts during that period. It has been increased to 6 per cent since 1 January 1951, so as to allow the Fund to be built up in such a satisfactory manner as to be able to meet all its potential liabilities.

More recent and accurate statistics have since established that the figure of 6 per cent is nearer the actual annual losses incurred through cyclones and droughts, and it is likely that this figure will be maintained.

COMPENSATION FOR DAMAGE

The loss during any cyclone or drought year is ascertained by comparing the yield of sugar per arpent* in that year on those estates in each factory area which have been selected by the Board for inspection, with the average yield of sugar per arpent on those estates during the three normal years immediately preceding. The average percentage of such loss is deemed to be the maximum applicable to the respective factory areas in which such estates are situated.

Should the Board consider that no estate which has been inspected within a factory area can be selected for the purpose of assessing the percentage of loss in such factory area, by reason of the neglect after a cyclone or drought to cultivate and maintain the sugar cane plantations on such estate, or for some other reason which may appear sufficient to the Board, the average percentage of loss in such factory area shall be deemed to be the average percentage of loss ascertained as above, of those estates in neighbouring factory areas which have been selected by the Board for inspection.

The rate of compensation per ton of sugar produced is determined by dividing the gross value of the total reduction in the tonnage of sugar of such estates in each factory area as have been selected by the Board by the total sugar production, during the cyclone or drought year, of the estates selected. The resulting figure represents the rate of compensation per ton of sugar produced applicable to the factory area, subject as provided below.

COMPENSATION TO ESTATES WITH FACTORIES IN RESPECT OF REDUCTION OF SUGAR PRODUCED FROM THEIR OWN CANES

Payment to estates with factories which have been selected for the purpose of assessing the percentage of loss in their factory area is based on the gross value of the actual reduction in the sugar tonnage produced from their own canes, ascertained in the manner provided in the first paragraph of the preceding section. Payment to estates with factories which have not been selected for assessing the percentage of loss in their factory area, is made at the rate as determined in the manner provided in the second paragraph of the preceding section.

* 1 arpent = 1·044 acre.

From the amount thus arrived at in either case, the following expenses are deducted, *viz*: the actual cost of manufacture, bags and transport to the docks in respect of all sugar short produced, the actual cost of cutting, loading and transporting the corresponding tonnage of canes calculated by reference to the basic extraction. To the figure thus obtained is added the increased cost of manufacture of the sugar actually produced, as determined by the Board, arising from the reduction in the crop. Compensation is paid at the rate of 95 per cent of the amount thus reached, the sugar producer being his own insurer for the first 5 per cent.

COMPENSATION TO MILLERS

Payment to millers is made at the rate determined in the third paragraph of the last section but one and on the total tonnage of sugar accruing to them from planters' canes during a cyclone or drought year. From such amount is deducted the actual cost of manufacture, bags and transport to the docks in respect of the reduction in such tonnage of sugar. To the figure thus obtained is added the increased cost of manufacture of the sugar actually produced from planters' canes as determined by the Board, arising from the reduction in the crop. Compensation is paid at the rate of 95 per cent of the amount thus reached, the miller being his own insurer for the first 5 per cent.

COMPENSATION TO PLANTERS

Payment to planters whose estates have been selected for the purpose of assessing the percentage of loss in their factory area is based on the actual reduction in the tonnage of sugar accruing to them as ascertained in the manner prescribed earlier. From such amount is deducted the actual cost of cutting, loading and transporting the corresponding tonnage of canes, calculated by reference to the basic extraction. Compensation is paid at the rate of 95 per cent of the amount thus reached, the planters being their own insurers for the first 5 per cent.

Planters whose estates have not been selected for the purpose of assessing the percentage of loss in their factory area are grouped according to the weighbridges and sidings used by them. They receive payment at the rate determined as described earlier, and on the total tonnage of sugar accruing to them. From such amount is deducted the actual cost of cutting, loading and transporting the tonnage of canes corresponding to the reduction in the sugar accruing to them, calculated by reference to the basic extraction. The result, multiplied by 95/100, represents the aggregate amount of compensation payable to those groups of planters, the planters being their own insurers for the first 5 per cent. Such amount is divided amongst the various groups of planters so that each group receives an amount which bears the same proportion to the aggregate amount as the loss sustained by each group bears to the total loss sustained by all groups.

It is provided in the law that the amount of compensation payable in respect of a factory area shall, if necessary, be reduced, so that in no case shall it exceed the maximum applicable to the factory area concerned, as defined earlier.

It is further provided that, when calculating the compensation payable to any estate, planter or group of planters, the Board may, in its discretion,

having regard to the circumstances of the case, take into account the reduction or increase in the area harvested and such other factors as may have unduly affected the loss sustained.

As stated earlier, the miller, by paying a premium on his sugars, insures the cost of manufacture of all the sugar normally produced by him, plus his normal profit. Therefore, in a cyclone or drought year, he should receive compensation both in respect of increased cost of production and of his normal profit, but the cost of manufacture, bagging, transport, storage and stevedoring of sugar which he has not produced should be deducted from the net value of the reduction, because otherwise he would, in certain cases, realize larger profits in a cyclone or drought year than in a normal year.

GENERAL REMARKS

To enable the Board to determine both premium and compensation payable, every miller, estate with factory and planter is under the obligation, by law, to furnish to the Board, through the miller, the required particulars.

A Bill meant to amend the Ordinance governing the Fund is to be introduced shortly into the Legislative Council so as to empower the Board to make advance payments on compensation due in respect of damage done by a cyclone or drought.

The reason for the amendment is that sugar producers are likely to be most in need of money during the period shortly following a cyclone or drought. The amendment will enable the Board to make advance payments in case of a cyclone or drought, pending final computation of the amount payable; the necessary adjustments being made when the compensation has been finally determined. It is proposed that such advances shall in no case exceed an amount representing 75 per cent of the compensation estimated to the time the advance is made.

The provisions of the Ordinance, in regard to the computation of both premium and compensation, appear to be complicated, but it must necessarily be so, as it should not be forgotten that it took forty years to arrive at an acceptable solution of the difficulties of insuring the sugar crop against cyclones and droughts and that Mauritius is the first country in the world to have adopted such an insurance scheme. The whole question was carefully considered by a thoroughly representative Committee and the present scheme is the outcome of their recommendations and was unanimously agreed to, not only by the representatives of the sugar producers, planters (large and small) and local government, but also by the Secretary of State for the Colonies.

The balance standing to the credit of the Fund at 31 December 1954, was Rs 75,026,792·80 and it is estimated that it will reach the sum of Rs 87,000,000 by the end of the present year.

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Studies in the Mineral Nutrition of Sugar Cane in British Guiana

II—The Mineral Status of Sugar cane as Revealed by Foliar Analysis

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The history of foliar analyses for diagnostic purposes in sugar cane

The application of the foliar diagnostic techniques of Lagatu and Maume (1930–1933) and Maume (1942) to the investigation of mineral status in sugar cane has, in general, been remarkably successful. The work of Craig (1938-1945), Halais (1938-1945) and of Halais (1944, 1946–1953), Feillafe (1949) and others in Mauritius established the technique on a permanent basis, and manurial practices have been based on foliar analysis for some years in this island, a special laboratory having been established for the purpose. The comprehensive investigations of Innes (1949–1952) and Innes and Chinloy (1953) in Jamaica have substantially revealed the major element status of sugar cane in Jamaica, having been spectacularly successful in the diagnosis of potassium status. Similar methods have been reported to be showing promise in Natal (du Toit, 1953) and useful information was recently published on the nutrition of sugar cane in Barbados (Robinson, 1953).

In Hawaii, although the particular technique of Lagatu and Maume and later of Thomas (1937, 1945) and his colleagues in continental U.S.A. were not systematically followed, a wealth of information on the mineral composition of sugar cane was collected as a result of the detailed investigations of Borden (1942–1946), Ayres (1933, 1936, 1937), Yuen and Hance (1939) and others. Parallel to this was the work of Clements (1942, 1950–53) and his colleagues, whose technique of crop control—now familiar to all sugar cane investigators under the name of 'crop logging'—was more ambitious in that the interaction of physiological and climatic factors additional to mineral nutrient status were taken into consideration. In Clements' technique blade tissue is used only for nitrogen, the analyses of the elongating leaf sheaths being preferred for the diagnosis of the status of potassium, phosphorus, calcium and magnesium.

The more recent work of Burr (1952–1954), Humbert (1953) and their colleagues utilizing radioactive tracer techniques has added valuable information to our knowledge of the mineral nutrition of sugar cane and will undoubtedly go far to remove imperfections in present methods.

Beauchamp (1940) and his colleagues have also used foliar analysis to good effect in Cuba; Bedsole and Breggar (1953) in Florida, Aughtry and Lunin (1953) in the Dominican Republic, and Bonnet (1953) and Samuels, Capo and Bangdiwala (1953) in Puerto Rico.

There are sound reasons why the utilization of foliar analysis has been particularly successful in sugar cane as compared to many other crops where the value of the technique has not been quite so apparent.

Sugar cane is, in the first place, a rapidly growing crop capable of producing dry matter at a faster annual rate than any other crop, and tissue composition is, therefore, more likely to reveal slight inadequacies in the rate of supply of nutrients. Secondly, in most countries where the crop is grown, there are at least some periods during the year when climatic conditions are not limiting and at which periods any suboptimal nutritional factors become dominant in their effect on growth and yield. Thirdly, it is tolerant of a wide range of soil conditions, possessing a root system capable of foraging widely for nutrients and considerably more resistant than most crops to minor element malnutrition. For this reason the macro-elements, nitrogen, potassium and phosphorus, have, in most countries, played a dominant role in the mineral nutrition of the crop.

Prior to the application of the foliar diagnostic technique in Mauritius some fundamental investigations on the physiology of sugar cane growth had been carried out in that island; Hill and Evans (1932) investigated the interactions of climatic factors and growth, Evans (1936) investigated the course of growth during the crop cycle and established differential rates of growth between the root system, stem, and leaves at different seasons of the year and at different stages in the life of the crop.

The growth increment curves of adequately manured and unmanured cane only showed significant differences during the period of active growth (the so-called boom period, when temperature and soil moisture are optimal) which normally occurs in the period mid-December to mid-April. Moreover, the cane crop had to be in the physiological stage of active growth, *i.e.* to be on the steeply rising part of the sigmoid growth curve. Finally, a suitable physiologically active tissue had to be selected as an index tissue—the chlorophyllous tissue of the third leaf from the apex, counting the rolled-up spindle as the first, being found to fulfil the requirements. The Mauritius technique therefore consisted of selecting a sample of these leaves from fields of plant cane seven or eight months old, or of ratoon canes five to seven months old during the boom period (December–April) after ensuring that moisture had been fully adequate for at least three weeks before the samples were taken.

The excellent physical texture of the volcanic soils of Mauritius and their adequate reserves of calcium, magnesium and micro-nutrients (other than a somewhat low base status in the highly leached super-humid regions) ensured that no major factors other than nitrogen, potassium and phosphorus were likely to interfere under these conditions.

Foliar diagnosis as practised by Craig and Halais (1938–1947) and Halais (1947–1953) was thus limited in its objectives, although adequate to the requirements of Mauritius where facilities for irrigation were limited and temperature as well as rainfall is a limiting factor in cane production for considerable periods of the year.

In the irrigated areas of Hawaii where the soil moisture factor is under substantial control it has been possible to extend the period when chemical and physiological analyses of tissues are effective in crop control. Moreover,

the growing of two-year crops which pass through two boom periods complicates the situation as compared to that in countries with a one-year growth cycle. The wider physiological approach necessary when the control of optimal water relations (made possible by modern irrigation practices) in addition to mineral nutrient status is the object, and where control of cane quality as well as tonnages is essential, is exemplified by the Clements approach to the problem.

However, there appears to be decisive evidence that Clements' methods are of the greater value in those regions where temperature, light intensity and other climatic factors are favourable, but where natural rainfall is so low that moisture control by manipulation of irrigation is dominant.

The Clements crop log technique when applied to the unirrigated high-rainfall areas of the Hawaiian islands where climatic factors are more variable and under less control has been demonstrated to be much less precise than in the high-sunshine, irrigated areas.

In fact there are undoubted interactions between climatic factors and foliar composition which have not yet been fully elucidated and the success of the diagnosis is highly dependent on the recurrence of uniform climatic conditions from season to season. Where such is not the case diagnosis becomes less reliable.

With respect to nitrogen, Samuels, Capo and Bangdiwala (1953) have shown that, in Puerto Rico, the rainfall which the crop has received has a marked effect on the critical nitrogen content at the time of sampling. These investigators have developed regression formulae to correct the critical nitrogen content for variations due to rainfall, and similar corrections may be made from sheath moisture determinations.

In Hawaii, on the contrary, temperature has been found to be the dominant factor affecting the critical leaf nitrogen value, and moreover, although the air temperature is involved, the temperature of the root system (in practice, soil temperature) is dominant: when the root temperature is as low as 64° F it becomes the major climatic factor affecting leaf nitrogen content.

Within 5–10° of the equator where temperature is reasonably uniform and moisture is almost always abundant, it appears to be possible to arrive at a stable value for optimal nitrogen content at a specific age of the crop. Even in the various climatic zones of the Hawaiian islands Humbert (1953) has shown that fields of certain estates which gave higher-than-average yields of sugar per acre were characterized by differences in the nitrogen–age curve of the crop as compared to average or lower-than-average fields.

The optimum foliar nitrogen is well known to be affected by age, and the physiological differences in the age curve for plant cane as compared to ratoons results in similar differences in nitrogen–age curves between plant cane and ratoons. The differences lie chiefly in the ages at which a certain nitrogen content is reached rather than in absolute differences in optimal nitrogen contents (Stender, 1953, Evans (unpublished work)). Burr (1954), however, considers foliar nitrogen content inadequate as a nitrogen index. Halais (1953) also found difficulties in relating yield to foliar nitrogen content, particularly in plant cane, and now uses ratoon foliar nitrogen in preference. Innes and Chinloy (1953, 1954) are using the increase in

foliar nitrogen resulting from nitrogen manuring, rather than the absolute foliar nitrogen as a more valuable index. Burr (1954) believes that the alcohol-soluble nitrogen content in the stem tissues at the base of the stalk holds promise. This fraction would represent incompletely assimilated nitrogen, the presence of which in any appreciable amount would be indicative of adequacy of nitrogenous reserves. The chief disadvantage of the foliar nitrogen index appears to be the small differences which accompany large changes in nitrogen applications.

Work in Mauritius, Hawaii and Jamaica has shown that the element whose status can be most reliably diagnosed is potassium. In Mauritius the rather wide range 1·35–1·65 per cent K_2O was regarded as optimal, whereas extensive investigations in Jamaica (Innes and Chinloy, 1952) narrow the critical range for this element to 1·4–1·5 per cent K_2O (1·1–1·2 per cent K) in the chorophyllous tissue of the third fully opened leaf at five months and this value appears to apply also to British Guiana (Evans *et al*, 1954).

In Hawaii, it is reported that Clements' critical value of 2·25 per cent K in the sugar-free dry matter of the elongating leaf-sheaths has proved to be a reliable index although Humbert (1953) from the analyses of log data from several estates reported that the critical value for potassium was believed to vary from 1·5 per cent K in the higher rainfall, low-sunshine areas to 2·0 per cent K in irrigated low-rainfall high-sunshine areas.

Humbert's evidence for this conclusion was indirect and was based on the assumption that, since total leaf nitrogen attained a minimum at a certain sheath potassium content, this potassium content was the optimal. He does not produce any experimental evidence to support this view, however.

With respect to phosphorus an optimum content of 0·45–0·50 per cent P_2O_5 in the chlorophyllous tissue of the third leaf first established in Mauritius appears to have been fairly generally accepted in other sugar cane areas, although Bourne (1950) in Florida and Bonnett (1953) in Puerto Rico find rather lower concentrations of phosphorus adequate. Recently Feillafe (1953) claims that confirmatory evidence for inadequate phosphorus is to be found in the disappearance or even reversal of the usual gradient in nitrogen content from the younger green leaves to the oldest green leaf.

However, under British Guiana conditions, the nitrogen gradient between the top visible dewlap leaf and the last green leaf in sugar cane suffering from various degrees of phosphorus deficiency, did not differ consistently from that in similar plants from plots in which the deficiency had been fully corrected. It appeared, on the contrary, that climatic conditions played a more important part in determining the nitrogen gradient from young to old leaves than phosphorus status.

The Clements critical value for phosphorus in the sugar-free dry matter of the elongating leaf sheaths is 0·080 per cent P. In practice it is acknowledged that this value is more reliable in defining phosphorus status at the boom period of growth.

Little work has been published on adequacy limits of calcium and magnesium. Clements (1951) states that he regards the normal level of calcium and magnesium in the sugar-free dry matter of the elongating leaf sheaths as 0·200 per cent Ca and 0·175 per cent Mg respectively. A few analyses

of the chlorophyllous tissue of the third leaf in Mauritius showed calcium contents from 0·30 per cent–0·50 per cent Ca and the writer in attempting to diagnose chlorotic symptoms in the leaves of cane in certain restricted areas of Mauritius found a very high calcium content (0·67 per cent Ca in the dry matter).

The writer has been unable to find any data in the literature on adequacy levels of the micro-nutrients in sugar cane. Work on elements other than nitrogen, potassium and phosphorus is, however, proceeding actively in British Guiana, Jamaica and Hawaii.

EXPERIMENTAL METHODS

The data which are presented in the present paper have been obtained during the last two years as part of a wide scheme of investigations into the nutrient status of sugar cane in British Guiana. This followed a rapid survey of mineral nutrition by means of rapid tissue tests the results of which have been published as the first paper in this series (Evans, 1954).

The methods used were as follows:

(*a*) Growing sugar cane in aerated nutrient cultures under conditions where all the essential elements were supplied and under conditions where each essential element in turn was withheld. The apparatus used for this work was identical to that used by Maskell, Evans and Murray (1952) and Hewitt (1952), except that the containers for the cane plants were larger. At the time when the withholding of an element had a pronounced retarding effect on growth and at the times when slight and acute deficiency symptoms of the element occurred, samples of the leaf having the top visible dewlap were collected and analysed for the element which had been withheld. In the case of some elements, analyses were only carried out when deficiency symptoms had started to show.

(*b*) A wide series of factorial fertilizer trials with nitrogen, potassium and phosphorus at three levels and with a comparison of 6 tons/acre limestone versus no limestone in split plots. Leaf samples from the 54 treatment combinations in 25 such trials were analysed when the plants were three months, four-and-a-half months and six months old. The results of 16 of these trials have been published as Part III of this series (Evans *et al*, 1954). Analyses were generally for N, P, K, Ca, Mg, Mn, and Fe, but a selected number of samples were further analysed for Cu, Zn, B, and Mo.

(*c*) A series of 3 × 3 × 3 factorial trials with potassium, calcium, and magnesium each at three levels.

(*d*) A series of similar factorial trials with potassium, phosphorus, and magnesium at three levels, but including also a comparison of supplementary trace elements versus no trace elements in split plots.

(*e*) A series of 3 × 3 factorial trials testing nitrogen alone, nitrogen plus limestone, and nitrogen plus potassium plus phosphorus in combination, with no trace element supplement, 150 lb./acre Du Pont fritted trace elements, and complete trace elements (excepting Mn and Fe) as commercial grade chemicals.

(*f*) The collection of samples of top visible dewlap leaves at four-and-a-half to five months old from ordinary commercial plantations all over the colony and the analysis of this material for micro-nutrients.

(*g*) The analyses of leaf samples from field-grown material showing deficiency symptoms or toxicity symptoms of any particular element.

Tissue Sampled.—Other than in trials where Clements log data were also required (in which case the elongating leaf-sheaths, *viz* the sheaths of leaves Nos. 3–6 counting the rolled spindle as No. 1 were used) the samples always consisted of 30–50 leaves showing the highest visible dewlap (*i.e.* the joint triangle or collar—normally coloured greyish or purplish at the joint of the lamina and the sheath). The middle 8 in. of these leaves was separated into chlorophyllous tissue and midrib, the latter being discarded. The fresh tissue was dried rapidly in a forced draught oven at 80° C, ground in a Christie Norris mill and stored in air-tight bottles until analysed.

OBJECT OF THE WORK

The aim of this investigation was first to determine the level of adequacy for each element in a selected sugar cane tissue, such that a further increase in the level of the element would not result in any increase in the yield of sugar per acre: secondly, to discover the range of levels of each element in the tissue under British Guiana conditions so that those in adequate amount, those deficient, and those in excess could be identified: thirdly, to establish the extent to which yields could be raised by bringing the levels of all nutrients to the optimum level.

In the case of the macro-elements, the quantitative data submitted refer particularly to plant cane; similar investigations on ratoon cane are now in progress.

RESULTS

Nitrogen

Leaf samples from 1,080 plots receiving nitrogen at three levels *viz* none, 4 cwt. and 8 cwt./acre sulphate of ammonia were analysed for total nitrogen at three, four-and-a-half and six months and yields of cane and sugar at harvest were available for each one of these plots. The spread of the dates of planting and harvesting was such that any seasonal drifts in climatic conditions would be largely ironed out.

Varieties used in the trials included B4098, B37161, B41227 and B34104.

The optimal nitrogen content was regarded as being the nitrogen content of the leaves from those individual plots in each trial which gave the highest yield of cane and sugar per acre. The highest yields were, in fact, in the range 65–72 tons of cane per acre at an average age of reaping of 13 months; in the same trials the lowest yielding plots (almost invariably those not given nitrogen) yielded at the rate of 28–40 tons of cane per acre.

In spite of the range in time of planting, in varieties and in the soil and climatic conditions on the different estates, the nitrogen levels associated with the highest yields in plant cane were remarkably constant. The foliar nitrogen content at the age of three months depends to a considerable degree on whether the total nitrogen application for the crop will have been completed by the age of six weeks (the usual practice) in which case the leaves will contain about 2·5 per cent N or whether half the application will have been made at six weeks, the remaining half to be applied at three months (the samples being, of course, collected immediately before the latter application) in which case the leaves should contain 2·2–2·3 per cent N.

In fact the nitrogen content at three months is not critical—there is still time to produce maximum yields by ensuring optimal nitrogen from this time onwards.

At four-and-a-half months the highest yields occur when the nitrogen content is 2·20–2·25 per cent and the value at six months should be 2·0–2·1 per cent.

A reduction of as little as 10 per cent in the foliar nitrogen content at four-and-a-half and six months is associated with substantially lower yields and a reduction of 20 per cent in foliar nitrogen content at these ages is associated with yields only a half of the maximum yields.

These levels of nitrogen are in close agreement with those regarded as being optimal by Stender (1953), Humbert (1953) and Clements (1953) in Hawaii. The nitrogen content at four-and-a-half to six months inclusive appears to be critical and is highly correlated with final yields.

The chief limitation of this foliar nitrogen index is that, whilst accurately defining the nitrogen status at the time of sampling, it does not reflect the nitrogen reserves, and nitrogen is sufficiently mobile within the cane plant to result in considerable withdrawals from the leaves used for sampling, if the reserves are inadequate. Healthy leaves supplied with normal amounts of nitrogen show quite marked visual symptoms of nitrogen deficiency within one week of being transferred to a nitrogen-free culture solution.

The very large yield difference resulting from small differences in foliar nitrogen has been recognized in other countries also, and constitutes the reason why attempts to improve the sensitivity have been attempted in several countries. In Hawaii, Burr (1953) favours the alcohol-soluble nitrogen fraction of the stalk as a more valuable index than foliar nitrogen. He holds the view that reserves of simple incompletely assimilated nitrogenous fractions are a better index of adequacy.

The writer has compared the sensitivity of the various sugar cane tissues and finds the elongating leaf-sheaths to be relatively insensitive and valueless as an index tissue. The total nitrogen of the brei or sawdust obtained by sawing through the centre of the three internodes nearest the soil was, on the contrary, somewhat more sensitive than the green leaf. However the closest diagnosis is obtained by simultaneous analysis of the leaf and the brei. The brei nitrogen level gives an excellent indication of whether or not a satisfactory foliar nitrogen level is likely to be maintained. Well nourished plants show nitrogen concentrations in the oven-dried brei from the lowest three internodes of 0·90–1·0 per cent at three months, 0·55–0·60 per cent at four-and-a-half months and 0·50 per cent at six months.

These are, however, only very tentative values as they are based on relatively few analyses. Confirmation of the foliar nitrogen index has been obtained from a separate investigation involving the crop logging of some 300 cane fields on various estates in the Booker group. In *Figure 1* the foliar nitrogen content of fields of the varieties B41227, B37161 and B4098 yielding over 60 tons cane/acre (average age 13 months) are plotted. No differences have been established between the different varieties.

Nitrogen Levels in Ratoon Cane.—Although only a few of the factorial fertilizer trials on ratoons have been harvested to date, a preliminary indication of optional foliar nitrogen in ratoon cane may be obtained by

plotting the nitrogen–age curve for the better yielding fields under ordinary estate cultivation.

In *Figure 2* the foliar nitrogen–age curve is plotted for B34104 giving 40 tons or over, B41227 giving 46 tons or over, B37161 giving 40 tons or over, and miscellaneous varieties giving 45 tons or over. Average age at cutting is $11\frac{1}{2}$–12 months. In both *Figures 1* and *2*, the analyses refer to the leaves sampled according to the Clements log schedule (leaves 3–6 counting the rolled spindle as No. 1); however, it has been found that there is very little difference between the nitrogen content of such samples and samples of leaves showing the highest visible dewlap.

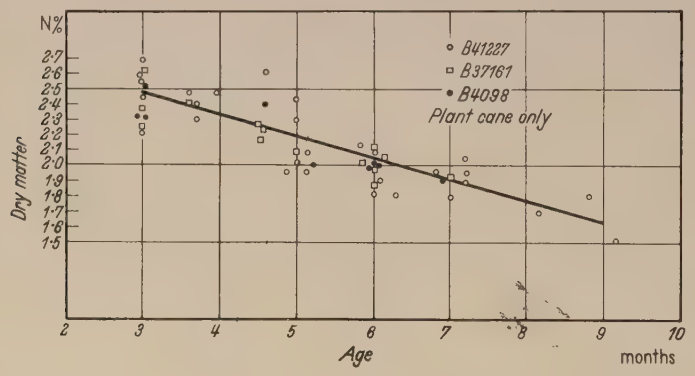

Figure 1. Fitted foliar nitrogen–age curve for fields under ordinary estate cultivation giving 60 tons or more cane per acre per annum

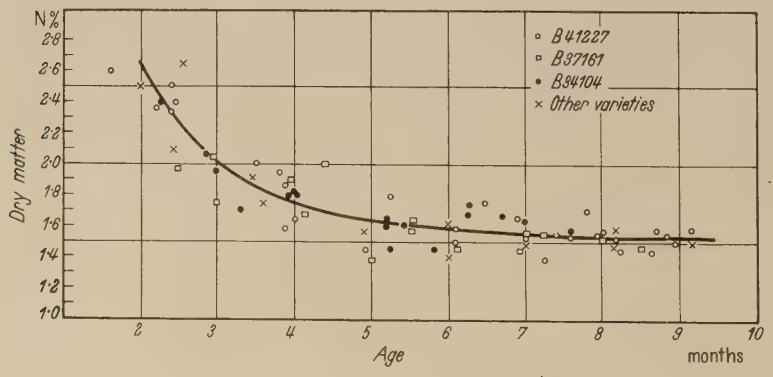

Figure 2. Fitted foliar nitrogen–age curve for ratoon fields under ordinary estate cultivation giving over 40 tons cane per acre

It is apparent that the foliar nitrogen–age curve differs considerably between plants and ratoons, there being a far more rapid drop in nitrogen content during the first five months of growth in ratoons as compared to plants. There is no evidence of any varietal effect on the foliar nitrogen-age curve.

Potassium

All the evidence which we have available, indicates that for maximum yields the foliar potassium content at four-and-a-half months and six months of age should be 1·20 per cent K. The proportion of trials giving a response to potassium was not as large as that giving a response to nitrogen, and the former trials were mostly confined to the East and West Coast, Demerara.

In a few trials in the Berbice district a response to potassium has been obtained even though the foliar potassium content of the control plants was 1·20 per cent K or more. However, in these cases, phosphorus was the limiting element and the application of potassium resulted in better phosphorus uptake, so that the yield response was, in fact, a phosphorus response and only indirectly due to potassium. In *Table 1* the relationship between foliar potassium content and yields in nine factorial fertilizer trials showing some response to potassium is shown.

Table 1. Leaf Potassium at four-and-a-half months and Associated Yields

Trial 1	%K	1·02	1·13	1·19	Trial 6	%K	1·08	1·18	1·29
	TCA*	41·5	46·6	47·9		TCA	45·2	46·1	44·5
Trial 2	%K	1·07	1·22	1·29					
	TCA	46·4	47·3	49·5	Trial 7	%K	1·02	1·13	1·20
						TCA	41·7	44·0	49·3
Trial 3	%K	1·10	1·19						
	TCA	46·8	48·3		Trial 8	%K	1·12	1·17	1·22
Trial 4	%K	1·15	1·23	1·28		TCA	37·8	41·4	40·7
	TCA	47·0	49·1	48·2					
Trial 5	%K	1·11	1·20	1·28	Trial 9	%K	1·14	1·17	1·22
	TCA	43·8	47·4	46·0		TCA	31·3	34·3	35·3

* Tons cane per acre.

In one exceptional case where potassium did not increase the yield although the index was somewhat low, it was shown that the calcium and magnesium status was marginal and the added potassium depressed the content of these two elements still further.

Since the indicated critical value for potassium (1·20 per cent K) is equivalent to 1·44 per cent K_2O, it is clear that the level conforms accurately to that established in Jamaica and Mauritius. The foliar potassium content appears to be constant between the age of three months and six months at least for the top visible dewlap leaves sampled, and a drop in the potassium content below the critical value for any lengthy period up to age six months is reflected in a reduction in tons cane per acre.

The Clements Potassium Index

Under British Guiana conditions the potassium content of the sugar-free dry matter of the elongating leaf-sheaths fluctuates violently when foliar potassium remains relatively constant. In general the sheath potassium in cane grown in the Berbice district reaches the Clements critical value of 2·25 per cent K and frequently exceeds this figure by a considerable margin. The adequacy of the potassium level in this area is confirmed by the absence

of responses to potassium fertilizers. On the East and West Coast, Demerara, it is only rarely that sheath potassium reaches 2·25 per cent and responses to potassium are frequently obtained in this area. In a general way, the Clements index is thus a useful criterion of potassium adequacy. When, however, one examines the results of individual trials in which the top visible dewlap leaves as well as the elongating sheaths from the same plots have been analysed, it is immediately apparent that the foliar index is a far more reliable diagnostic tissue in relation to final yields of cane and sugar per acre.

In ratoon cane in particular, sheath potassium may be consistently very substantially below 2·25 per cent—sometimes as low as 1·0–1·4 per cent K—when the potassium content of the top visible dewlap leaves of the same plants may be in the range 1·0 to 1·2 per cent K. In such a case the foliar analyses would indicate a moderate but distinct potassium deficiency, whereas the sheath analysis would indicate an extremely severe deficiency if the Clements value of 2·25 per cent were applicable. In such cases the foliar values have proved to be the better indicators of final yields of cane and sugar. Alternatively, it may prove to be the case that the critical value of potassium in the sugar-free dry matter of the elongating leaf-sheaths may be substantially below 2·25 per cent K, particularly in ratoons, under British Guiana conditions.

In general, uptake of potassium is rendered difficult in very wet weather when soil aeration is particularly poor and drainage impeded. In accordance with this fact, any treatment that improves tilth, such as improved drainage, limestone applications, *etc*, also improves potassium uptake. Inadequate potassium occurs most frequently on the silty clays and the pegassy soils.

Phosphorus

In most of the factorial fertilizer trials laid down on the East and West Coast Demerara estates, where responses to phosphorus have been obtained, the increases in tonnage have been associated with increases in the P content of the leaves from values below 0·20 per cent P to values of 0·20–0·22 per cent P. Where the phosphorus level in the top visible dewlap leaves was raised beyond 0·22 per cent P, there was no further increase in yield.

In the Berbice district where phosphorus deficiency conditions ranging from mild to acute are widespread the highest levels of phosphate fertilizers used (8 cwt. superphosphate per acre) frequently failed to raise P levels in the sampled leaves to more than 0·19 per cent P at three months, 0·16–0·17 per cent P at four-and-a-half months, frequently falling as low as 0·13 per cent at six months. Nevertheless some of the plots giving these levels of phosphorus yielded well (58–65 tons of cane per acre at 12 months) even though they had passed through sharp periods of drought.

In perusing the analytical data for phosphorus content in the top visible dewlap leaves from all kinds of experimental samples over a period of two years, it was quite apparent that there was a general overall drop in the level of phosphorus at each dry period. It so happened that most of the trials on the East and West Coast Demerara were laid down three to six months before those in the Berbice district and the lower and falling levels

of foliar phosphorus in the Berbice trials could well have been due to the drier conditions at the time of sampling.

That this was indeed the case was shown by R. B. Austin, Field Superintendent of two of the Berbice estates, and confirmed by R. A. Yates for the other two Berbice estates.

Austin calculated the regression between the foliar P index and the amount of rain that had fallen during the four weeks immediately prior to taking the samples. Assuming that all plots receiving the highest dose of phosphate fertilizer were adequately supplied with phosphorus—an assumption which is fully justified by the responses to phosphate fertilizer in terms of cane and sugar—the regression equation for phosphorus adequacy in terms of the inches of rain falling during the four weeks prior to sampling was:

$$\% \text{ P} = 0{\cdot}0049814 \text{ R} + 0{\cdot}1577$$

for plant canes in the age group three to six months.

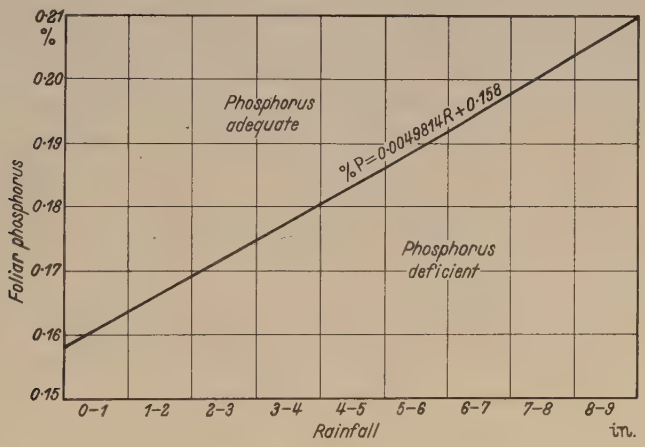

Figure 3. Inches of rain falling in previous four weeks

This curve is plotted in *Figure 3*. These data would indicate a minimum P adequacy level (when the monthly rainfall has been 1 in. or less) of 0·1577: an almost identical curve was obtained when all the data for the middle phosphate level (P_1 dose) were treated in the same way. Yates found a minimal value of 0·1592 for samples collected at Rose Hall and Albion estates. The P adequacy level when 8 in. of rain had fallen in the previous four weeks was 0·21 per cent P and this value did not rise with heavier rainfall. Indeed, Yates' data indicate that the P adequacy level may reach a maximum when the rain which has fallen in the previous four weeks is 8–12 in. and there appears to be a definite decline when the previous month's rainfall exceeds 20 in.

The adequacy level for phosphorus in the foliar chlorophyllous tissue during the age period three to six months when climatic conditions are favourable (as indicated by a rainfall of 8 in. or more in the previous four

weeks) is thus 0·21 per cent P—which is equivalent to 0·48 per cent P_2O_5. This value agrees perfectly with the critical value established in Mauritius and found to apply in Jamaica and Natal (0·45–0·50 per cent P_2O_5). In Mauritius the favourable climatic conditions would be automatically assured since samples are only collected during the boom period of growth.

The influence of rainfall on the phosphorus index is, however, of particular significance in a country like British Guiana, where temperature is always favourable and rainfall is the most important variable, since it enables a correct diagnosis to be made at all times of the year.

It also has a bearing on the phosphorus–age curve. Phosphorus analyses carried out (as part of a Clements log investigation of over 300 cane fields in the colony) at intervals of five weeks demonstrate that there is no apparent upward or downward trend of phosphorus in the sugar-free dry matter of the elongating leaf-sheaths.

Insofar as the foliar phosphorus content at three months, four-and-a-half months and six months of age in the factorial fertilizer trials is concerned, it is of interest to note that those trials which passed through the three to six month stage of their growth in the wet season generally show a slight increase in phosphorus content between three months and four-and-a-half months levelling off between four-and-a-half months and six months. Those trials which passed through the three to six month stage of their growth in dry weather, on the contrary, show a continuous decline in the phosphorus content from three months to six months. This decline has now been shown to be mainly a rainfall effect and not an age effect. On balance it is doubtful whether there is any significant upward or downward trend in the foliar phosphorus level between three months and six months when all climatic effects have been eliminated.

This would imply that leaf samples for diagnosis could be taken at any time between three and six months under British Guiana conditions, but they are in practice collected at four-and-a-half to five months of age in plant cane.

The Correction of Phosphorus Deficiency

The correction of phosphorus deficiency is most easily achieved by the use of triple superphosphate (45 per cent water-soluble P_2O_5) at the rate of 4 cwt./acre. Increasing the dose to 8 cwt. seldom gives any further increase in yield of cane and sugar over 4 cwt. although the phosphorus content of the cane juice is thereby increased. It is almost universally the case, however, that the application of limestone in addition to phosphate fertilizers facilitates the entry of phosphorus into the cane and results in significant increases in yield. There is ample evidence also that the phosphorus status of the cane is markedly affected by limiting physical features of the soil restricting root growth.

At Rose Hall estate, for example, the mechanical conversion of the usual 36 ft. wide beds to 12 ft. wide beds raised the foliar phosphorus content from 0·12–0·14 per cent P to 0·18–0·20 per cent P without addition of any phosphate fertilizer. The improved physical condition of the soil due to better drainage and the resulting increase in root growth was responsible for the improved phosphorus status.

Calcium

A positive response to limestone was obtained in a high proportion of the fertilizer trials. In most cases this was not a response to calcium as a nutrient, but was due to the part played by limestone in (*a*) increasing phosphorus uptake, (*b*) increasing potassium uptake, (*c*) preventing the uptake of toxic amounts of iron and/or manganese, (*d*) making molybdenum available, or (*e*) generally improving soil physical conditions. In a few trials, however, a straight response to calcium as a nutrient was obtained.

Healthy canes rooted and transferred into an aerated nutrient solution lacking calcium grew very slowly after four or five weeks. At this stage the top visible dewlap leaf assayed 0·16 per cent Ca. The canes were left in the nutrient solution for a further period until calcium deficiency symptoms made their appearance in the older leaves and the top visible dewlap leaves again sampled. The calcium content of the leaves had fallen to 0·103 per cent.

Leaf samples from several fields showing varying degrees of calcium deficiency were analysed with the following results:

(*i*) Sample from Uitvlugt estate showing mild visual symptoms of calcium deficiency in association with molybdenum deficiency symptoms. Calcium content (top visible dewlap leaves) 0·15 per cent Ca.

(*ii*) Sample from La Bonne Intention estate showing acute visual symptoms of calcium deficiency to the extent that growth completely stopped and younger leaves were chlorotic and only a few inches long.

Field	*Foliar Calcium as* Ca
Vreidslust 32	0·055–0·069 per cent
Vreidslust 33	0·067–0·084 per cent
Vreidslust 34	0·081–0·084 per cent

From the comparison of plants grown in nutrient solution lacking calcium, and field plants showing acute calcium deficiency symptoms, it would appear that well marked starvation symptoms appear when the calcium content falls below 0·10 per cent Ca and mild symptoms including the typical leaf spotting may be present when calcium content is within the range 0·10–0·15 per cent Ca.

On the other hand, in a factorial fertilizer trial on a pegassy (tropical peaty) soil, certain plots which yielded from 65 to 72 tons of cane per acre assayed 0·185 per cent Ca at four-and-a-half months and 0·190 per cent Ca at six months. One must therefore conclude that these concentrations may be regarded as adequate.

An apparently straight response to calcium was obtained in one trial on the East Coast Demerara. The calcium contents of the fully nourished and deficient plants were as follows:

Age	+ Ca	— Ca
3 months	0·190	0·184
4½ months	0·190	0·166
6 months	0·198	0·174

The response in this case was small—2½ tons of cane per acre.

It is tentatively assumed that the critical calcium content in the top visible dewlap leaf in plant cane is approximately 0·16–0·18 per cent Ca.

As mentioned previously, responses to limestone dressings are frequently obtained, particularly in the Berbice estates when the calcium content of the unlimed plants has been as high as 0·22–0·24 per cent Ca, but there is conclusive evidence that such responses are indirect and chiefly due to the improved phosphorus uptake in the presence of limestone.

In plant cane one would not be far wrong in suspecting calcium deficiency whenever foliar calcium falls below 0·18 per cent Ca and in assuming adequacy whenever the concentration exceeded 0·20 per cent Ca.

In general, for the relatively few comparisons made, foliar calcium was considerably higher than the calcium content of the elongating leaf-sheaths —frequently twice as much. It would, therefore, appear that the lower critical level of calcium in the sugar-free dry matter of the elongating leaf-sheaths is very considerably lower than the value tentatively accepted by Clements (0·20 per cent Ca)—probably in the vicinity of 0·10 per cent Ca.

There are distinct possibilities that foliar calcium content is affected by climatic conditions, as phosphorus has been shown to be, but low calcium appears to coincide with periods of very wet weather. In some acid soils temporarily water-logged, the incidence of calcium deficiency may be so sudden that the typical calcium deficiency symptoms in the older leaves are not produced, but on the contrary, the growing point is immediately affected and the young leaves are small and chlorotic and there is little or no stem elongation.

It is possible also that the critical calcium content may be somewhat lower for ratoons than for plant cane, since calcium contents below 0·17 per cent have been found at four-and-a-half to six months of age in ratoons which were yielding fairly normal crops. However, the calcium status of ratoon cane has not yet been fully investigated.

Nutritional calcium deficiency is of quite frequent occurrence in British Guiana, but the factors involved in calcium uptake need further elucidation.

It has been shown that ammonium sulphate which is used as the source of nitrogen has a major effect in promoting calcium uptake. It frequently raises the calcium status more than a corresponding dressing of a calcium salt. The application of limestone at 6 tons/acre generally significantly raises the foliar calcium content, although in some cases only slightly, and ratoons grown on land given 6 tons of limestone when they were plant canes have sometimes shown low foliar calcium content.

Magnesium

Rooted cane plants transferred into aerated culture solution lacking magnesium grew well for several weeks: there was evidently a considerable reserve of magnesium in the plants. After two months in the magnesium-free nutrient solution the top visible dewlap leaf still contained 0·126 per cent Mg: after a further two months, slight symptoms of magnesium deficiency appeared in the older leaves. By this time the magnesium content of the foliar tissue sampled had fallen to 0·05 per cent Mg. This is, therefore, the level at which deficiency symptoms begin to show.

In the series of factorial fertilizer trials testing three levels of N, P and K with split plots of limestone versus no limestone, the magnesium content of the foliar tissues varied from 0·10 to 0·40 per cent Mg. Where the magnesium content approached the latter figure, potassium was generally deficient and the application of potash fertilizer normally brought down the foliar magnesium to a value of 0·20–0·25 per cent Mg. In one particular trial (Ogle estate Field Sparendaam 29) potash and phosphate fertilizers in the absence of sulphate of ammonia reduced the cane yields, whereas at the higher level of nitrogen the two elements produced a positive response. The plots in which yields were low showed visual symptoms of magnesium deficiency and when analysed were found to contain 0·03–0·05 per cent Mg. The high nitrogen plots supplied also with potash and phosphate assayed 0·10–0·15 per cent Mg in the foliar tissues and yielded 70 tons of cane per acre.

All the trials show a highly significant effect of sulphate of ammonia in promoting magnesium uptake and an equally depressing effect of potassium. The role of phosphorus is less consistent—depressing magnesium uptake at low nitrogen levels and promoting uptake at high nitrogen levels.

Obviously in the Sparendaam trial magnesium was already marginal and in the absence of adequate sulphate of ammonia to promote its uptake, the effect of the fairly large applications of potassium and phosphorus was to impede magnesium uptake to the degree of inducing visual starvation symptoms and greatly reducing cane yields. On the contrary, several plots have given excellent yields of cane with the foliar magnesium index in the range 0·10–0·15 per cent. The value of 0·10 per cent Mg has been tentatively adopted as the lower limit of adequacy, although the critical value may be slightly lower than this, but certainly higher than 0·05 per cent Mg. Good yields have also been obtained in trials where the foliar magnesium content has been 0·35–0·40 per cent Mg and a range of 0·10–0·35 per cent appears to be quite normal.

On the other hand, growth failure in one locality was associated with a foliar magnesium index of 0·60 per cent Mg. In this case calcium and potassium indices were low, nitrogen abnormally high (3·6–3·8 per cent N) and the older leaves showed considerable rusting.

This condition existed in about 500 acres of reclaimed savannah land on Ogle estate. The variety B34104 was highly susceptible to these conditions. Use of the varieties B37161 and B4362, applications of lime and potash and a small application of superphosphate has resulted in crops in which the foliar composition is almost normal and the magnesium index has fallen to 0·25 per cent Mg. Other than the possibility of inducing a magnesium deficiency by the application of excessive amounts of lime and potash to areas where the soil magnesium status has fallen on account of heavy leaching, no serious magnesium problem is likely to occur in British Guiana. As in the case of calcium, the magnesium content in the foliar tissue and in the sugar-free dry matter of the leaf-sheath was determined on the same material. The mean foliar magnesium content was 0·252 per cent Mg and the mean sheath magnesium content was 0·179 per cent Mg; the sheath magnesium content was thus about two-thirds of the foliar Mg index.

Manganese

Manganese is apparently fairly mobile in the cane since, when rooted canes were placed in aerated culture solutions devoid of manganese, some months elapsed before mild symptoms appeared. The manganese content of the foliar tissue at the appearance of mild manganese deficiency symptoms was 24 p.p.m. in the dry matter. As some measure of adequacy, the writer found 40 p.p.m. manganese in the foliar tissue of healthy sugar cane in Mauritius.

Routine manganese and iron determinations were carried out on all the 3N × 3P × 3K factorial trials both in the presence and absence of limestone.

It was evident that foliar manganese content was high under local conditions: manganese varied from 120–560 p.p.m. in the dry matter of the chlorophyllous tissue of the leaf, most of the values lying in the range of 150–250 p.p.m.

A frequency table of foliar manganese content based on 1056 analyses is given in *Table 2.*

Table 2. Manganese Content in Parts per Million of Leaf Dry Matter

P.P.M.	100–150	150–200	200–250	250–300	300–350	Over 350
Frequency of occurrence	216	294	315	123	81	27

In general, the application of ground limestone at 6 tons/acre resulted in a reduction in the foliar manganese content, but the degree of reduction varied within wide limits (from 10–100 per cent). As might be expected, the highest manganese contents were found in very acid soils, particularly pegassy clays, and were associated with low calcium status. The young leaves of sugar cane show mild interveinal chlorosis in the presence of excessive manganese. There appears to be a varietal susceptibility to the development of these symptoms, B34104 being particularly susceptible. They are associated with a manganese content of 350 p.p.m. or more in the leaf tissue, but this content of manganese does not appear to be alone responsible for any decrease in yield of cane. Poor growth associated with low calcium status and manganese in excess of 450 p.p.m. in the leaf has been noted in some areas.

Since manganese determinations were made on leaf samples from several 3N × 3P × 3K factorial trials, a considerable amount of data was available for testing the effect of nitrogen, potash and phosphate fertilization on foliar manganese content. No significant effects showed up, which is evident from the summary of available data in *Table 3.*

Sugar cane is fairly tolerant of high manganese content, but many other plants, legumes in particular, are not, and some of the latter show striking manganese toxicity symptoms in normal cane soils of the colony. Manganese toxicity is thus a factor which would have to be taken into consideration when new crops are considered. Heavy liming and improved drainage leading to good soil aeration reduce manganese uptake quite considerably.

Table 3. Mean Foliar Manganese Content in Parts per Million

Limed				*Unlimed*			
Levels of major elements				*Levels of major elements*			
	0	1	2		0	1	2
Nitrogen	204	214	200	Nitrogen	217	228	229
Potash	206	207	204	Potash	226	227	221
Phosphate	204	204	207	Phosphate	224	223	226

Note.—The levels denoted by 0, 1 and 2 were as follows:—

Nitrogen	(Sulphate of ammonia)	0, 4 cwt., 8 cwt. per acre.
Potash	(Muriate of potash)	0, 3 cwt., 6 cwt. per acre.
Phosphate	(Superphosphate)	0, 4 cwt., 8 cwt. per acre.

Iron

As recorded in the first paper of this series, no symptoms of iron deficiency were observed in the field in British Guiana, but grey node symptoms associated with a heavy deposition of iron at the nodes are frequently seen in wet weather. The only observations on deficiency levels of iron were obtained from canes grown in iron-free culture solution. The iron content of chlorotic leaves was below 5 p.p.m.

Since the lowest iron content from field-grown samples was about 40 p.p.m. in the dry matter, with iron contents up to 200–250 p.p.m. in plants showing the grey node symptoms of iron toxicity, it was apparent that iron was ample in all cases and was excessive in several instances. A frequency table of foliar iron content based on some 1,100 iron analyses is given in *Table 4.*

Table 4. Iron Content in Parts per Million of Leaf Dry Matter

P.P.M.	40 50	50–60	60–70	70–80	80–100	100–120	Over 120
Frequency of occurrence	66	214	275	194	148	82	97

Differential nitrogen, potash and phosphate fertilization had no large or consistent effect on the foliar iron content under British Guiana conditions, and even the application of ground limestone at 6 tons/acre had a negligible effect in reducing the iron content (see *Table 5*).

Table 5. Mean Foliar Iron Content in Parts per Million in Dry Matter

Limed				*Unlimed*			
Levels of major nutrients				*Levels of major nutrients*			
	0	1	2		0	1	2
Nitrogen	83	77	72	Nitrogen	78	78	77
Potash	77	73	74	Potash	78	77	77
Phosphate	75	73	77	Phosphate	78	79	76
General mean *75·5*				General mean *77·6*			

Levels of major nutrients were as described for manganese. There is a possibility that in the presence of lime, sulphate of ammonia may decrease the iron content slightly but not in the absence of lime; otherwise there are no marked effects of major nutrients on iron content.

Copper

The dearth of published analytical data on the micro-nutrients on sugar cane leaves is particularly surprising in the case of copper, since areas of copper deficiency have been prominent, particularly in Florida and parts of Louisiana.

Values of 17–24 p.p.m. in the dry matter of the young leaf-sheaths have been reported from Hawaii (*H.S.P.A. Comm. Rep.*, 1952). For fodder grasses in Florida Forsee (1953) reported that copper contents of 3–4 p.p.m. in the leaves were associated with copper deficiency which would cause a decreased yield in some grasses.

By applications of copper dressings adequate to eliminate deficiency symptoms the copper content was raised to 6–7 p.p.m., while values as high as 12 p.p.m. were occasionally found. Mulder (1950) has established a critical copper level of about 8 p.p.m. for five-week oat plants (stem and leaves).

In British Guiana samples of soils from Blairmont estate spectroscopically analysed in the U.S.A. (Bourne 1949) showed total copper in the range 0·0001–0·0009 per cent. Paul (1953) records values of soil copper soluble in N/2 acetic acid at 48 p.p.m. and 19 p.p.m. respectively for virgin and exhausted pegasse soils.

In the present work rooted sugar cane stalks were placed in aerated nutrient culture solutions fully supplied with all elements except copper, and their growth compared with that of similar canes in complete nutrient solution including copper (supplied at 0·02 mg/l).

The copper content of the chlorophyllous tissue of the leaf showing the highest visible dewlap from fully nourished plants in culture solution was 4·5–5·0 p.p.m. in the dry matter. There was a slight reduction in growth in the parallel series where no copper was supplied and major nutrients were purified by recrystallization only. Foliar copper content of comparable leaf tissue in this series was 3·5–3·7 p.p.m. in the dry matter.

Complete elimination of copper from the nutrient solution by stringent purification methods resulted in the appearance of deficiency symptoms, in the form of interveinal chlorosis interrupted by islands of green tissue. In some cultures the typical semi-wilted condition of the leaves occurred, but no apparent chlorosis was seen. The copper content of the chlorophyllous tissue of the sampled leaves was in the range 0·5–1·0 p.p.m. in the dry matter. It is apparent, therefore, that visual deficiency symptoms of copper only become apparent at extremely low concentrations of copper, but that a growth response would be expected within the range of 1·0–3·5–4·0 p.p.m. Plants with foliar copper contents of 4·5–5·0 p.p.m. were apparently adequately supplied since the plants grew rapidly and bore healthy looking leaves. It was decided, therefore, tentatively to regard the critical level of copper in the chlorophyllous tissue of the leaf showing the top visible dewlap at the age of three to six months as about 4 p.p.m. in the dry matter.

Some copper assays were made on material from 3N × 3P × 3K factorial fertilizer trials, but in addition a general survey of copper levels was made in material from ordinary estate fields along the sugar belt—some six hundred fields being sampled when the cane was four to five months old. Sixty to 80 leaves showing top visible dewlap were selected at random from each field, dried and finely ground and a sample of 5 g dry matter wet-digested with nitric, sulphuric and perchloric acids. Copper was determined by the method of CHENG and BRAY (1953).

The analysis of the copper contents of samples from the factorial fertilizer trials showed that the major nutrients N, P, K and limestone at the rate applied had no consistent effect on the foliar copper content.

A frequency table for foliar copper content for all estates managed by Bookers Sugar Estates Ltd. is given in *Table 6.*

Table 6. Foliar Copper Content in Parts per Million in Dry Matter

P.P.M.	Below 4	4·0–5·0	5·1–6·0	6·1–7·0	7·1–8·0	8·1–10·0	Above 10·0
Frequency	20	132	234	81	99	81	6

It is evident that the vast majority of the samples are adequately supplied with copper on the basis of the tentative critical value adopted. The samples which assayed below 4·0 p.p.m. were, in fact, within the range 3·5–4·0 p.p.m. and were predominantly B34104. It is not apparent how much importance should be attached to these few low values as the variety B34104 has been rapidly deteriorating in recent years and frequently shows abnormally low values for major nutrients also. However, there is little doubt that, particularly in some of the Berbice estates, foliar copper may occasionally be approaching the limiting value for cane. When carrying out some pot culture experiments with soils from Port Mourant estate from the same fields which were used by HARDY (1949) for determination of phosphate status, the chlorotic symptoms described by Hardy (*loc. cit.*) in tomato plants were reproduced.

As a result of positive responses in tomato to interveinal injections of Cu and Mo, dressings of copper sulphate and sodium molybdate were applied and these resulted in the disappearance of the chlorotic symptoms, but it is not clearly established whether the action of these elements was direct, or whether it could be due to antagonism of manganese which was present in the leaves in fairly high concentration (up to 1,350 p.p.m.). The copper content of the chlorotic leaves was however only 15 p.p.m. as compared to 30–40 p.p.m. in the healthy plants.

The general conclusion is that in the sugar lands of British Guiana, at least in their present acid condition, copper is not likely to be limiting yields, but that it is possible that very restricted areas which are marginal with respect to copper nutrition may be encountered and that in such areas, for crops other than sugar cane and with higher demands for copper, inadequacy of this element might be expected.

Zinc

In samples of soils from Blairmont estate assayed for zinc spectroscopically in the U.S.A. the report recorded zinc as being ' looked for but not found ', (Bourne, 1953). On the contrary Paul (1953) reported 32 and 42 p.p.m. of zinc in the N/2 acetic acid extract of exhausted and virgin pegasse soil respectively.

In the first paper of this series (Evans, 1954a), zinc was qualitatively found to accumulate in the nodal region of sugar cane stalks.

A simplified procedure for the assay of zinc in sugar cane leaf material has been published by the writer (Evans, 1954b). This method was utilized in a survey of the zinc content of sugar cane foliar tissue, supplemented in several instances by the *Aspergillus niger* assay method.

Relatively few assays of zinc in sugar cane leaf material are recorded in the literature: values of 70–100 p.p.m. in the dry matter of the leaf-sheaths have been recorded from Hawaii. The writer has recorded as much as 130 p.p.m. zinc in foliar material from sugar cane plants grown in a special potting mixture. Although leaf material from soil-grown plants is much lower in zinc, it is nevertheless apparent that zinc is accumulated in the leaf in much larger amounts than copper.

A rough approximation of the levels of adequacy of zinc in the leaf tissue was more difficult to estimate from nutrient culture work since it was difficult to keep the cultures from contamination with zinc from air-borne dust particles in the centre of Georgetown where the cultures were located.

Chlorotic leaves resulting from zinc deficiency gradually picked up enough zinc to attain a pale green colour by contamination of the cultures. The lowest foliar zinc content obtained from controlled nutrient culture was 15 p.p.m. On the other hand, the foliar zinc content of field grown cane giving good yields was frequently as low as 20–25 p.p.m.

Although a basal critical value cannot be suggested from the data available, it is believed that a zinc content of more than 20–25 p.p.m. represents adequacy, since such a concentration has been associated with normal yields of cane.

Table 7. Effect of N, P, K and Limestone on Foliar Zinc Content (Means of 27 Analyses in each Category)

Limed				*Unlimed*			
Levels of major nutrients				*Levels of major nutrients*			
	0	1	2		0	1	2
Nitrogen	31	33	36	Nitrogen	29	31	34
Potash	32	34	33	Potash	30	32	31
Phosphate	33	33	34	Phosphate	30	32	31
General mean *33·3*				General mean *31·3*			

Zinc assays on leaf samples from N, P, K factorial fertilizer trials established the fact that sulphate of ammonia consistently increased foliar zinc content whereas potash and phosphate were without effect. Limestone applications appeared to result in a slight increase in zinc content (see *Table 7*).

A number of zinc determinations have been carried out on leaf samples from estate fields selected at random.

The frequency of occurrence of various ranges of foliar zinc content is given in *Table 8.*

Table 8. Frequency of Occurrence of Various Zinc Contents in Chlorophyllous Tissue of Sugar Cane Leaves

P.P.M. zinc	20–25	25–30	30–35	35–40	40–45	45–50	50–60	60–70	70–80	80–100	Over 100
Frequency of occurrence	13	51	66	57	12	7	5	2	4	2	2

It may be concluded from the zinc assays carried out to date that it is unlikely that zinc is either in short supply or in excess under normal cane growing conditions in British Guiana.

Boron

Boron deficiency symptoms were more readily produced in nutrient culture than for most other micro-nutrients. The use of rainwater collected on plastic cloth and of twice recrystallized A.R. chemicals sufficed to produce marked visual symptoms of boron deficiency. These symptoms were substantially like those described by MARTIN (1921) except that none of the galls on the lower surface of the lesions which were described by this author were seen.

Top visible dewlap leaves were collected at intervals from plants showing visual deficiency symptoms and boron was assayed by the 1-1'dianthrimide method of GORFINKIEL and POLLARD (1953, 1952). This analytical method appears to offer very considerable advantages over previously published methods of boron determination in plant material. The boron content when slight but distinct deficiency symptoms were showing was 4·0–5·0 p.p.m. in the dry matter. Healthy apparently fully nourished plants growing in culture solution contained 15–20 p.p.m. of boron in the dry matter. The tentative adequacy level has, therefore, been placed at some value between 5·0 p.p.m. and 10 p.p.m. Relatively few boron determinations have been carried out in comparison with other micro-nutrients ; some values below 10 p.p.m. have, however, been encountered recently in field-grown cane. The frequency of occurrence of various ranges of boron content in the leaf material is given in *Table 9.*

Table 9. Frequency of Occurrence of Various Boron Levels in the Foliar Material

P.P.M.	Below 10	15–20	21–25	26–30	31–35	36–40	41–45	46–50
Frequency of occurrence	20	10	22	27	28	17	9	2

It is interesting to note that samples taken during the drier months of the year showed minimum values of 15 p.p.m. boron in the dry matter. During

the wet months of 1954 low values have been frequently encountered. The boron content of some samples from the east coast estates were as low as 6 p.p.m. A trial at Rose Hall estate also showed low boron—4 p.p.m. at three months increasing to 7–8 p.p.m. at four-and-a-half months and 10 p.p.m. at six months. However, this trial gave a reasonable tonnage of cane (averaging 48–50 tons/acre). It is possible that seasonal deficiency of boron due to leaching of available boron in wet weather may occur fairly frequently, but the economic significance of this requires further investigation. Field trials involving treatments with trace element mixtures including boron have been laid down, and some trials have been reaped. The results of these trials showed increased yields from the application of trace elements when sulphate of ammonia alone was applied, but no responses where adequate amounts of limestone or of phosphatic fertilizers in addition to sulphate of ammonia had been applied.

Molybdenum

The preliminary examination of fresh leaf-sheath tissue by rapid tissue test methods had indicated that the content of molybdenum was likely to be low, but this was not by itself surprising in view of the very low molybdenum content found in many plants (see, for example, Robinson and Edgington (1954), Laycock (1954) where normal values of 0·1–0·2 p.p.m. of molybdenum in the dry matter are recorded).

When the writer accompanied Mr. Steindl, pathologist of the Queensland Bureau of Sugar Experiment Stations, on an inspection tour of British Guiana sugar estates to determine the status of ratoon stunting disease in the colony, unusual leaf symptoms were seen in the variety B4098 at Uitvlugt estate. In fact, nodal symptoms resembling ratoon stunting disease were present in this cane and these were the first to be seen in the colony in spite of careful search of several estates daily for five days. There were some abnormal features about the field: it had grown very well as plant cane and was ' drawn down ' for planting material at seven months: the regrowth was excellent and it was ' drawn down ' for planting material a second time in very wet weather. This time regrowth was very poor and it was apparent that on this occasion the silty clay had lost its texture. The cane was particularly stunted, however, the unidentified leaf symptoms were only noted on B4098; although almost equally stunted, B41227 in the same field did not show the leaf symptoms. Neither Mr. Steindl nor the writer were familiar with the leaf symptoms and after Mr. Steindl's visit terminated, an investigation was carried out to determine the cause of the symptoms.

The symptoms, which were confined to the fully opened and mature leaves and which increased in severity with age of the leaf, consisted of yellow streaks in the chlorophyllous tissue of the leaf. The streaks were 1–3 mm in width and varied in length from a few millimetres to a centimetre or more and were suggestive of the leaves having been lightly daubed with yellow by means of a fine camel hair brush. The streaks were generally fewer towards the base of the leaf. The yellow streaks developed some reddish pigmentation in the centre, which finally formed lesions of necrotic tissue.

Analysis of top visible dewlap leaves showed that the canes were inadequately supplied with several nutrients particularly calcium, potassium and phosphorus, and were extremely low in molybdenum. Whilst canes supplied with molybdenum in the form of 2–3 lb. sodium molybdate per acre ceased to produce the leaf symptoms, the stimulus to growth was very small. On the other hand, there was a marked response to 5 tons limestone per acre and a spectacular response (resulting in 100 per cent increase in the final crop of cane harvested) to 4 cwt. superphosphate and 3 cwt. muriate of potash. However, an acre plot in this field which was uprooted, forked and replanted with the cuttings taken from the stunted B4098 showed excellent growth without the fertilizer amendments, although they did respond (to the extent of 15–20 per cent) to potash and phosphate fertilizer.

The stunted growth of the B4098 canes was primarily due to loss of tilth and poor physical texture in this highly acid silty clay soil resulting in a restricted root system which failed to supply the necessary nutrients for its own growth and thus brought about a deficiency of the elements mentioned. The leaf symptoms—present only on the mature and older leaves—were apparently due to molybdenum deficiency, since when this element was supplied leaves free from symptoms were produced. On the other hand the addition of limestone, potash and phosphate fertilizers resulted in healthy plants from which the symptoms disappeared.

As the assay of molybdenum at the levels expected is often subject to analytical errors of procedure, check samples were analysed by N. K. Peterson of the New Jersey Agricultural Experiment Station and by E. J. Hewitt of the Long Ashton Research Station. The molybdenum content of the leaves of B4098 showing the symptoms described above was determined by Peterson to be 0·05 p.p.m. in the dry matter. Assays of the same material made by the writer varied from 0·03–0·05 p.p.m. A composite sample of leaves from adjoining fields of the estate but not showing any symptoms were found by Dr. Hewitt to contain 0·38 p.p.m. of molybdenum.

It has been possible to obtain more data on the critical level of molybdenum from the analyses of control and treated plants from several field trials which were laid down to investigate responses to molybdenum, and from samples subsequently obtained which showed the leaf symptoms which the writer has associated with molybdenum deficiency.

The field trials were 8×8 latin squares with the following treatments:

(1) Controls (untreated).
(2) 3 tons limestone in furrow, 2 tons broadcast.
(3) 5 tons limestone broadcast and incorporated.
(4) 5 tons limestone +3 cwt. hyperphosphate (finely ground raw rock phosphate) +3 cwt. muriate of potash.
(5) 3 cwt. hyperphosphate +3 cwt. muriate of potash.
(6) 3 lb./acre ammonium molybdate.
(7) 3 cwt. hyperphosphate +3 cwt. muriate of potash +3 lb. molybdate.
(8) 5 tons limestone +3 cwt. hyperphosphate +3 cwt. potash +3 lb. molybdate.

Bulked leaf samples from one of these trials (Uitvlugt estate) were analysed by the writer and also by J. Spector at the Imperial College of Tropical Agriculture, Trinidad. The two sets of analytical data are given in *Table 10.*

Table 10

Treatments	PPM Molybdenum	
	I.C.T.A.	Georgetown
1	0·090	0·10
2	0·155	0·20
3	0·160	0·20
4	0·185	0·22
5	0·080	0·08
6	0·360	0·32
7	0·500	0·47
8	0·790	0·73

The results are in reasonably close agreement and show:

(1) The considerable increase in molybdenum content brought about by liming alone.

(2) A fourfold increase in molybdenum content of the leaves brought about by an application of 3 lb./acre of molybdate.

This particular trial gave a response of 2 tons of cane per acre to molybdenum on a crop of 55 tons cane per acre and this response did not reach significance. It must therefore be concluded that a molybdenum content of 0·08 p.p.m. in the dry matter represents adequacy or near adequacy in sugar cane, but deficiency symptoms of this element appear below 0·05 p.p.m.

A second trial of the same type at La Bonne Intention Sugar Estate showed marginal molybdenum content in the controls. This trial was sampled and analysed for molybdenum at the ages of three months, four-and-a-half months, and six months. The molybdenum data are given in *Table 11.*

Table 11. Molybdenum in Parts per Million (in parentheses) in Dry Matter, and Vegetative Growth Index

Treatments (as in Table 10)	3 months	4½ months	6 months	Mean V.G.I. all collections
1	0·08 (372)	0·14 (613)	0·16 (531)	505
2	0·25 (414)	0·29 (626)	0·30 (559)	533
3	0·17 (375)	0·24 (621)	0·27 (558)	518
4	0·18 (436)	0·22 (624)	0·24 (559)	540
5	0·08 (420)	0·14 (633)	0·14 (563)	539
6	0·19 (399)	0·33 (637)	0·29 (554)	530
7	0·17 (393)	0·35 (625)	0·27 (555)	524
8	0·20 (432)	0·55 (631)	0·50 (571)	545

Samples of 30 leaves showing highest visible dewlap on which the molybdenum assays were carried out were weighed fresh and the weights in grams (vegetative growth index) are shown in parentheses in *Table 11.*

The latter figure has in general shown a high correlation with cane tonnage. The evidence indicates that if molybdenum stimulated growth the effect would have been slight, probably under 5 per cent. Unfortunately no harvest data were obtained as the estate staff cut half the trial for planting material at eight months old and burned and harvested the remainder without warning. Further trials of this type are in progress, but the results are not yet available.

Molybdenum assays have been made on samples from some of the $3N \times 3P \times 3K$ factorial fertilizer trials.

Table 12. Effect of Major Elements on Molybdenum Content

	Levels of major elements		
	0	1	2
Sulphate of ammonia	0·48	0·35	0·25
Superphosphate	0·37	0·33	0·37
Muriate of potash	0·37	0·36	0·34

The mean values in *Table 12* (each based on 36 analyses) show that sulphate of ammonia significantly decreases foliar molybdenum content whereas potash and phosphate have no significant effect.

The frequency distribution of the molybdenum assays carried out to date is given in *Table 13*.

Table 13. Parts per Million Molybdenum in Dried Chlorophyllous Tissue of Sugar Cane Leaves

P.P.M.	0·05 or less	0·06–0·10	0·10–0·15	0·15–0·20	0·20–0·30	0·30–0·40	0·40–0·50	Over 0·50
Frequency of occurrence	2	4	4	13	40	22	6	6

SUMMARY

A study of the use of foliar analyses as an aid in the diagnosis of the nutritional status of sugar cane in British Guiana has been carried out.

In plant cane maximum yields of sugar per acre were associated with the following minimal values of nutrient elements in the chlorophyllous tissues of the leaf showing the highest visible dewlap or collar at the ages indicated.

	3 months	*4½ months*	*6 months*
Nitrogen (N% dry matter)	2·5	2·2–2·3	2·0–2·1
Potassium (K% dry matter)	1·20	1·20	1·20
Phosphorus (P% dry matter)	0·21	0·21	0·21

(Note.—Phosphorus is affected by rainfall ; the above level assumes adequate rainfall (8–9 in.) during the four weeks preceding sampling.)

Calcium (Ca% dry matter)	0·17–0·18	0·17–0·18	0·17–0·18
Magnesium (Mg % dry matter)	0·08–0·10	0·08–0·10	0·08–0·10

The status with respect to micro-nutrients reflected ample to excess manganese (minimum level required 40 p.p.m.; level found 100–400 p.p.m.):

ample to excess iron (minimum level required 15–20 p.p.m.; level found 40–250 p.p.m.): generally adequate copper (minimal level required, 4·0 p.p.m.; level found 4·0–14·0 p.p.m.): generally adequate zinc (minimal level required about 15 p.p.m.; level found 20–60 p.p.m.): occasional inadequacy of boron—particularly during wet periods (minimal level required 5 p.p.m.; level found 4–40 p.p.m.): occasional inadequacy of molybdenum (minimal level required 0·04–0·08 p.p.m.; level found 0·04–0·40 p.p.m.).

The optimal nitrogen content is in substantial agreement with that found optimal in Hawaii: the values for potassium and phosphorus are consistent with optimal values in several other cane-growing territories. No critical values for the remaining elements have, as far as the writer is aware, been published for sugar cane. The calcium status of sugar cane in British Guiana is frequently very low but high yields of cane may be obtained with calcium in the range 0·18–0·30 per cent Ca and magnesium in the range 0·08–0·30 per cent Mg provided that the levels of the other elements are adequate. The required levels of the micro-nutrients have been determined from plants grown in nutrient cultures except in the case of molybdenum, the level of which has been obtained from field responses.

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Studies on Mango (Mangifera indica *L.*) *Fruit Set in Puerto Rico*

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INTRODUCTION

The mango (*Mangifera indica* L.) is one of the most important fruit crops of tropical and sub-tropical regions. In some areas the fruit is of considerable commercial interest. Puerto Rico, for example, has exported over 10,000 crates of mangoes, mostly to the continental United States, in each of the past three years, and this is but a small fraction of the Island's production. This industry shows every sign of expansion, especially as markets develop in temperate areas of the world.

As the demand for mangoes increases, methods of efficient production assume greater significance. Yields often are disappointing, since the trees typically produce many flowers but relatively few mature fruits. Factors which have been recorded as affecting yield include: high ratio of staminate to perfect flowers (Popenoe, 1920), biennial bearing (Singh, 1948), diseases (Ruehle and Wolfenbarger, 1948), insect pests (Wolcott, 1933), fertility relationships (Sen *et al*, 1946, Spencer and Kennard, 1955), and cultural practices (Sen, 1943). These conditions are discussed by Mukherjee (1953) in his extensive review of the literature pertaining to the botany, cultivation, and uses of the mango. In order to study in detail the conditions responsible for the characteristic low yields of mangoes in Puerto Rico, a series of experiments were initiated.

INVESTIGATIONS

Mature trees (approximately 30 years of age) of 15 varieties located in the orchards of the Federal Experiment Station at Mayaguez were employed in various aspects of these studies. Flowering and bearing data on these trees, growing on a Catalina clay soil, have been collected for the past four years. Complying with the usual cultural practices in Puerto Rico and many other areas where the mango is grown, sprays to control insects and diseases were not applied to the trees.

Sexuality of Mango Flowers and Susceptibility to Thrips Injury

From a study of floral morphology it became apparent that in this species wide varietal differences exist in ratios of staminate to hermaphroditic and, rarely, pistillate flowers, and in susceptibility to thrips injury. A low percentage of perfect flowers capable of giving rise to fruits, and a high incidence of insect damage, could result in poor set.

The small, pinkish-cream flowers of mango are borne on large, terminal panicles which may contain several thousand blossoms. Not all of the flowers

are capable of developing into fruits, since, in addition to the perfect ones, there are staminate flowers, which in some varieties are in the majority.

In both types of flowers, there is usually only a single pollen-bearing stamen, although the undeveloped primordia of four others are often evident. Perfect flowers have a green to yellow ovary surmounting the central disk. Developing gynoecia were observed in sectioned material of flowers in early stages of differentiation. In many flowers, this development did not keep pace with that of other floral parts and resulted in ' unisexual ' or staminate flowers. In most of the varieties investigated, this suppression was first noted at about the time microsporocytes were delimited. Apparently, each flower possesses the potential for both sexes, but many fail to express femaleness.

For the purpose of determining ratios of imperfect to perfect flowers, panicles were collected from six mango varieties, and all the buds approaching anthesis (*i.e.*, buds that would open in one day or less) were examined (*Table 1*). The variety Totafari possessed the lowest ratio of perfect to staminate flowers, 149 to 827, while Divine had the highest ratio, 571 to 387.

Table 1. Incidence of Perfect, Staminate, and Thrips-damaged Flowers in Six Varieties of Mango

Variety	*Total flowers examined*	*Perfect flowers*		*Staminate flowers*		*Sex not classified**		*Thrips-damaged flowers*	
	Number	*Number*	*per cent*	*Number*	*per cent*	*Number*	*per cent*	*Number*	*per cent*
Amini	1,070	540	50·5	507	47·4	23	2·1	462	43·2
Cambodiana	779	416	53·4	307	39·4	56	7·2	579	74·3
Divine	966	571	59·1	387	40·1	8	0·8	80	8·3
Martinique	1,048	573	54·7	469	44·8	6	0·6	157	15·0
Mullgoa	852	206	24·2	616	72·3	30	3·5	314	36·9
Totafari	1,000	149	14·9	827	82·7	24	2·4	158	15·8
Mean	953	409	42·9	519	54·5	25	2·6	292	30·6

* Flowers too badly damaged by thrips for classification.

Inspection of these flowers revealed that many were damaged, apparently by insects. Field and laboratory studies showed that this damage was caused by members of the *Thripidae* (thrips). A single species, not yet identified, was responsible for most of the injury. Females of these minute insects have a saw-like ovipositor with which they penetrate the young buds and deposit their eggs through the perianth within the flower, often within the ovary. The eggs hatch and the immature forms feed on the pollen and floral tissues, particularly the ovary and the disk upon which the ovary rests. All stages from eggs to mature forms were noted in living flowers and sectioned material. Of the varieties studied, Cambodiana appeared to be most susceptible, with 74·3 per cent of its flowers damaged, while Divine had only 8·3 per cent. A combination of a low percentage of hermaphroditic flowers and high susceptibility to thrips damage, as apparent in the variety Mullgoa, may result in a substantially reduced yield.

Anthracnose, a disease caused by *Colletotrichum gloeosporioides* Penz., which often has been reported to cause low set, was noted as infrequently attacking the flowers; however, this disease became serious on the developing fruits. The very low rainfall during flowering may have delayed the development of the pathogen.

Pollination in Relation to Fruit Development

The large numbers of imperfect and thrips-damaged flowers reduce the potential amount of fruit, but not sufficiently to account for all instances of low yields. In order to determine whether or not pollination is necessary for carpel development, flowers of six trees, including four different varieties (Amini, Cambodiana, Paheri, Peter's No. 1) were either pollinated within 3 hr following anthesis, or pollination was prevented by emasculation and covering, or by emasculation and stigma excision. All flowers employed were in bud and about to open. Pollen was obtained from mature anthers of flowers of the same panicle, but not the same flower, by means of a spear-point needle which was sterilized by immersion in 70 per cent ethanol between transfers.

Table 2. A Comparison of the Effect of Pollination and Two Methods of Pollination Prevention on Fruit Development in Four Mango Varieties

Variety	*Emasculated and covered*		*Stigma excised and flower emasculated*		*Hand pollinated*	
	Flowers treated	*Carpels developed*	*Flowers treated*	*Carpels developed*	*Flowers treated*	*Carpels developed*
Amini #1	—	—	460	—	—	—
Amini #2	331	—	1085	—	126	5
Amini #3	—	—	230	—	—	—
Cambodiana	40	—	70	—	—	—
Paheri	216	1	143	—	284	11
Peter's No. 1	87	1	—	—	50	2
Total	674	2*	1988	—	460	18†

* These fruits dropped when they were 3 to 5 mm in length.
† Fruits more than 10 mm in length.

None of the 674 emasculated and covered flowers, and none of the 1,988 emasculated flowers with excised stigmas, developed into mature fruits (*Table 2*). However, two of these flowers produced fruits which dropped before attaining a length of 5 mm. Eighteen of the 460 hand-pollinated flowers produced fruits. These observations indicate that pollination is necessary for carpel development in these varieties.

Production and Viability of Pollen

Pollen of 15 mango varieties was studied to determine whether pollen production or viability could be factors contributing to poor fruit set. The average number of grains per anther was determined by stripping the pollen from 20 mature, unopened anthers into a known volume of water. An aliquot of constant volume was transferred to a microscope slide and the

number of grains counted. Stainability was shown by the reaction of at least 300 grains to a standard potassium iodide–acetic acid solution. Germination percentages were computed from grains developing on nutrient agar and on stigmas of both the same variety and those of the 'native' (Turpentine) mango at about 28°C. Pollen transfers in all cases were made from freshly opened stamens by means of a camel-hair brush. Stigmas used were from recently opened flowers brought into the laboratory and pollinated immediately. The flowers were maintained on moist filter paper in closed vials. Four hours later the stigmas were examined microscopically and the percentage germination calculated for each variety.

The average number of pollen grains shed per anther varied from 271 for Paheri to 648 for Haden (*Table 3*). The mean for the 15 varieties was 410 grains. Popenoe (1920) also reported that the mango produces comparatively few pollen grains, often not more than 200 to 300 per anther. The number of normal sized, well-filled, viable grains, as indicated by stainability, was good for all varieties. Totafari pollen had the lowest viability (72·1 per cent) and D. B. Alphonse the highest (94·2 per cent). The average germination on 1 per cent agar plus 20 per cent sucrose exceeded 78 per cent for all varieties, ranging from 66·3 per cent (Totafari) to 91·8 per cent (D. B. Alphonse). Pollen germination on stigmas of the same variety or on those of the 'native' mango averaged about 10 percentage points lower than on nutrient agar.

Although the pollen of the varieties studied displayed high initial viability, environmental conditions may greatly reduce its effectiveness. When pollen was left on dry filter paper in sunlight for 3 hr at 30–35°C, the germination on nutrient agar was reduced to 40 per cent. Pollen left 7 hr or longer under the same conditions did not germinate. Thus it is possible that the limited number of grains produced, together with the effects of light and temperature, may play a role in reducing fruit set.

Pollen Transfer in Relation to Anthesis

Since carpel development is dependent on pollination, studies concerning actual mechanisms and conditions of pollen transfer were undertaken. For pollen examinations, the flowers were tagged in the field before anthesis and collected at 6, 12, 24, and 36 hr after opening. Two collections, each on a different date, were made from flowers of eight varieties (D. B. Alphonse, Amini, Cambodiana, Divine, Martinique, Mullgoa, Paheri, Totafari) during the early part of blossoming. The same procedure was followed near the end of the blooming period for six of these varieties; flowers were not obtainable at this time from Amini or Totafari. For the purpose of this investigation, a single pollen grain on a stigma was considered to constitute pollination and, although many more grains were often found, pollination in general was meagre.

Six hours after anthesis only 16·1 per cent of the stigmas from early flowering had been pollinated, and even after 36 hr less than one-third of the stigmas showed adhering pollen. Immediate periods of 12 and 24 hr gave 20·3 and 23·1 per cent pollinated stigmas, respectively. The limited increase of the 24 hr figure over the 12 hr one probably is due to darkness (7.00 p.m. to 6.00 a.m.). Data from late flowering appear to follow much

the same trend as noted for early blossoming, except that the percentage of pollinated stigmas was about 25 per cent lower, *i.e.* 12·8 per cent after 6 hr and 24·9 per cent after 36 hr. Varietal differences concerned with pollination were not found.

These data and complementary observations indicate that pollination in mango may be adequate if only a small fraction of the pollinated carpels from the multitude of flowers produced result in developing fruit. But since there apparently is little correlation between the numbers of pollinated stigmas observed and numbers of fruit set, the comparatively small number of grains on a high proportion of the stigmas may be significant. Thirty-seven per cent of those pollinated carried 50 or fewer grains and 19 per cent bore 10 or less.

Table 3. Pollen Production and Viability in Fifteen Varieties of Mango

Variety	*Average grains per anther**	*Stainability†*	*Pollen germination†*		
			On nutrient agar	*On stigmas*	
				Same variety	*'Native' variety*
		per cent	per cent	per cent	per cent
Amini	446	88·3	78·7	68·2	64·5
Bulbulchasm	394	80·9	76·1	59·7	62·0
D. B. Alphonse	327	94·2	91·8	74·1	68·9
Cambodiana	403	85·6	83·2	62·5	65·1
Divine	296	82·1	72·8	60·5	56·9
Haden	648	76·8	70·9	58·6	62·1
Itamaraca	363	93·8	86·6	79·3	78·8
Martinique	292	90·8	86·1	65·9	67·8
Mullgoa	537	81·7	70·5	67·2	64·7
Paheri	271	92·5	89·2	80·9	79·0
Peter's No. 1	380	75·8	70·5	67·6	69·1
Pico	463	84·5	78·2	76·9	75·5
Singapur	490	87·5	78·9	74·3	66·4
Totafari	304	72·1	66·3	63·2	70·6
'Native' (turpentine)	535	89·0	78·4	73·8	—
Mean	410	85·0	78·5	68·8	68·0

* Average of 20 anthers.
† Based upon counts of at least 300 grains.

As previously reported by the authors (1955), the stigmas of mango have a very limited period of receptivity. Studies on the varieties Amini, Mullgoa, Paheri, and Totafari revealed that less than 10 per cent of the pollen grains placed on stigmas in the field 6 hr after flower opening produced tubes that penetrated the stigmatic surfaces. Stigmas aged 12 hr or older were not at all receptive. When the time of pollen transfer and the receptivity of the stigmas are considered together, it becomes apparent that only a small percentage (*ca.* 16 per cent) of mango carpels could be effectively pollinated, that is, pollen transferred to them while the stigmas were receptive. In view of the tremendous numbers of flowers per tree, this figure may seem

adequate, but a number of factors contribute to a substantially lower actual figure or percentage. Some of the pollen may not have been viable (*Table 3*), or from mango, or on receptive areas of stigmas. Also, for these studies, a single grain on a stigma constituted pollination. Another observation which may have considerable bearing on pollination concerns the dehiscence of anther-sacs. The anthers of mango generally do not shed pollen until 2 to 4 hr following anthesis. The period of greatest stigmatic receptivity, therefore, often does not coincide with pollen shedding from the same flower. This tendency to proterogyny, or maturation of stigmas before anthers, was also noted by SEN *et al* (1946) as not only limiting self-pollination, but also effectively reducing natural pollen transfer.

Insects in Relation to Pollen Transfer

From the foregoing studies on pollination, it was apparent that a lack of natural carriers might be responsible for the limited pollen transfer and subsequent low yields of fruit. Collections were made from the inflorescences of the variety Cambodiana during January (early flowering) and March (late flowering) for the purpose of determining the composition of the insect faunas associated with mango flowers at these times. The insects were taken by means of a double net, a coarse outer one and an inner one of very fine weave, placed over the intake hose of a vacuum unit (KENNARD and SPENCER, 1955). The use of these two nets effectively separated the large insects and plant debris from the smaller, more easily lost forms such as midges and thrips. Collections were made representing three periods during the day: 6.00 to 10.00 a.m., 12.00 to 3.00 p.m., and 5.00 to 8.00 p.m.

At early flowering, a total of 856 insects representing the following 13 orders were collected: Coleoptera, Collembola, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Siphonaptera, Thysanoptera, and Trichoptera. The Diptera made up almost one-half (48·6 per cent) of the total number of insects collected in January and, of these, the midges accounted for approximately two-thirds. One-fifth (20·7 per cent) of the early collections were hymenopteran forms of which 21 per cent were bees (*Apoidea*), and 10·7 per cent of the same collections were members of the Thysanoptera (thrips). Representatives of the 10 other orders accounted for less than 20 per cent of the insects from early flowering.

A marked change was noted in the composition of the insect fauna taken at late flowering when 533 insects were collected. No members of the Collembola, Odonata, Siphonaptera, or Trichoptera were taken. The only order collected at this time but not found in January was Dermaptera. Dipteran types still out-numbered all other orders; however, their relative frequency dropped 12 per centage points to 36·8 per cent. More of the large flies and fewer midges were taken; in fact, the latter made up less than one-half of the Diptera. The relative number of thrips increased to bring their percentage to 24·8, while the Hymenoptera made up only 11·6 per cent of these collections. Very few bees were found, 1·3 per cent as compared to 7·1 per cent in the early collections. The Hemiptera accounted for over one-fifth (20·5 per cent) of all the insects taken in these late collections, whereas they made up only 6 per cent of the early collection.

Certain orders (Hemiptera and Thysanoptera) were better represented in the morning collections, while others (Diptera, Lepidoptera, *etc*) are found more frequently during the evening. Over 40 per cent of the Hymenoptera, including *Apoidea*, were taken between the hours of 12.00 noon and 3.00 p.m.

Observations concerning insect behaviour during flower visitations and examination of them for pollen, disclosed that very few effective pollinators, *e.g.*, *Apoidea*, were present. There are a number of reasons why the larger insects, especially the bees, are the most effective agents for transfer of mango pollen. These reasons include: (1) limited pollen from a single stamen borne at a considerable distance above and off-centre to all other floral parts except the stigma, (2) the pollen adheres in relatively large, pollinia-like clusters in the early stages, and (3) although the single stigma and stamen usually are pressed together when the flower opens, they separate quickly so that by the time the anther-sacs dehisce, the stigma has been thrust above and away from the stamen. Unless the insects visiting the flower for nectar or pollen are fairly large, they are not likely to come into contact with the stigma. Very few of the many midges and thrips examined were found with attached pollen grains. Averages for these forms carrying pollen from three collections were: midges, 1·5 per cent and adult thrips, 2·8 per cent. On the other hand, every bee collected from mango inflorescences yielded at least a few pollen grains. The honeybee, as it probes into the flower, turns around and around on the perianth, brushing against both stamen and stigma, and this action appears to be an effective pollination mechanism.

CONCLUSIONS AND SUMMARY

The typical, variable, and often low yield of mango trees involves two fundamental problems: fruit set and drop of immature fruits. The results of studies concerning the first problem, and reported here, show the existence of a complex interrelationship among the various factors affecting carpel development.

Failure of the gynoecia to develop normally, especially in varieties such as Totafari, where less than 15 per cent of the flowers were found to be hermaphroditic, reduces the number of potential fruit. Examination of the flowers also revealed considerable thrips damage which further limits possible fruit set. Inasmuch as pollination is necessary for carpel development, pollen production and transfer are of paramount importance. A high initial viability of the small quantity of pollen produced was noted for the varieties studied. Environmental conditions such as low humidity, high temperature, and bright sunlight, however, reduce the germination of the grains. Effective pollination is limited further by the asynchronous maturation of anther and stigma. The importance of this phenomenon in relation to fruit set is heightened by the lack of insect carriers. Since the stigmas are receptive for but a few hours following anthesis which usually occurs during the early morning hours, the delay in anther dehiscence, together with the very few pollinating insects present, impede effective pollen transfer. Apparently, there is a direct correlation between the number of carriers present, such as *Apoidea*, and pollination.

Certain factors and their interrelationships were noted as contributing to low fruit set in mango. Two of these are the high incidences of imperfect flowers and thrips damage. The most significant factors to be revealed by these studies, however, appear to be ineffective pollination due to a lack of transferring agents, limiting period of stigmatic receptivity, and proterogyny. The problem of low yields in mango also involves premature fruit drop, a serious condition in Puerto Rico and many other areas.

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Book Reviews

SOIL CONSERVATION IN THE SUDAN

J. H. K. Jefferson. Ministry of Agriculture, Khartoum. 159 *pp.* (illus.)

When soil conservation as a necessary corollary of optimum land use is only very slowly being appreciated by the layman, it is encouraging to read of an Administration, in a country the size of Europe, so enlightened as to have a Soil Conservation Service. It is unfortunate, however, that the title of the book describing the work of this Service should be so misleading with respect to the contents. This most readable little book could have been more appropriately called ' Some problems of land-use in the Sudan '. It is precisely this and an attempt to alter for the better the present form of land-use which has been the task of the Service.

The author in his introduction refers to his story, and in the unravelling one begins to appreciate the immensity of the country. In fact, this is one of the main virtues of the book—its portrayal of the size of the problem being tackled. If in this capacity it lays further emphasis on the author's own words, ' In the Sudan there is a very large area indeed of potential food-growing land ', then it will serve a valuable purpose.

One cannot help but comment on the curiously structured Soil Conservation Board referred to on p. 13 which did not include a soil specialist. This lack is reflected in later developments, particularly since the work deviated from plain conservation into the more complex problem of land-use. Mistakes and failures quoted during the ' look-see ' phases of the work might have been circumvented if correct advice had been sought. This means much when time and resources are limited.

A number of photographs are included in the text. These seem rather pointless and convey little to the foreign reader. An aerial photograph of a ' hafir ' would have been much more revealing.—T.A.J.

SOIL AND WATER CONSERVATION ENGINEERING

Richard K. Frevert *et al.* John Wiley & Sons, Inc., New York, 1955. 447 *pp.* (illus.) $8·00 U.S.

The authors are to be congratulated on producing in a concise form up-to-date information on a number of subjects relative to soil conservation based on research in the United States. This book has been written primarily for use in that country, but much of the information provided has universal application. A typical example is a sentence on terracing. ' Since terracing requires additional investment and causes some changes in farming procedures, it should be considered only where other cropping or soil management practices, singly or in combination, will not provide adequate control.' This, and other sentences, indicate clearly that, while

the authors are specialists, they are fully aware of the economic implications involved in soil conservation work.

In a book of this kind one would have expected some reference to road construction and road drainage.

There are adequate plans, charts, and graphs to illustrate facts mentioned in the text and at the end of each chapter there is a list of references. There are also appendices: these contain data and tables required for computing hydrological data.

This book will be very valuable to all students of soil conservation. It can also be recommended for use by estate managers who have soil erosion problems to solve.—W.J.B.

REPORT ON THE 1950 WORLD CENSUS OF AGRICULTURE. VOLUME I—CENSUS RESULTS BY COUNTRIES

F.A.O., Rome, 1955. 10*s*

The results of the world census of agriculture, to which many countries devoted great efforts in 1950 at the request of F.A.O., have been long and anxiously awaited. The present volume is the first of three, the second being planned to deal with the methodology of the census, and the third with an analysis of the main subjects included.

Volume I is, however, at present far from complete, containing results from only 32 countries. It is in loose-leaf form, and it is stated that further instalments for incorporation will be published as they become available. The small number included is disappointing, since preliminary publication of census results from 64 countries has already been made in the *F.A.O. Monthly Bulletin of Agricultural Economics and Statistics*. The present instalment includes neither the United Kingdom nor the United States. It does include 23 British colonial territories, though here again we miss certain ones which have already individually published their own figures of the census, *e.g.* Nigeria and Basutoland.

The presentation of the statistics leaves much to be desired. In the crop acreage figures ' millet and sorghum ' are lumped together, and so are ' sweet potatoes and yams '. What would a temperate country think of figures which did not distinguish between say, barley, oats and rye ? The heading ' arrow-root ' appears from internal evidence to include a wide variety of root crops from *Maranta* to *Colocasia*. Under Uganda, no figure is given for bananas or plantains, the main food crop of the country, although estimates of the acreage are frequently published in the reports of its Agricultural Department. American terminology is used in the main, so that inhabitants of British tropical territories (far more numerous than American) will have to look for cassava under ' manioc ', and chillies under ' pimento '.

1950 ought to be a golden year for agricultural historians, as being the first in which they can look for even approximate world statistics of crops and livestock to form a standard for comparisons. It is to be hoped that on completion of this publication it will indeed prove to be so.—G.B.M.

THE PLANT QUARANTINE PROBLEM

W. A. McCubbin, M.A. Ejnar Munksgaard Ltd., Copenhagen, 1954. 255 *pp.* (illus.) £1 13*s* 9*d*

Although devoted to quarantine problems of the U.S.A., there is much to commend this book to those concerned with, or interested in, agriculture in any part of the world.

Mr. McCubbin's easy style and his lucid treatment of all the ramifications of this complex subject turn what may seem at first most unpromising material into a work which is both extremely readable and instructive.

Against the biological background—the nature and types of pests and diseases, the diversity of their hosts, the natural barriers to their spread, and the natural and man-made agencies aiding their dispersal—the author reviews the social and economic implications together with the legal and administrative measures which have been invoked in the efforts to combat or control the numerous real or potential dangers which constantly threaten a wide range of crops.

The problem, the principles of control, and, perhaps equally important, the limitations of available control measures, are outlined by quoting the golden nematode potato root parasite as a current example of importance, and this is followed by a useful discussion, couched in very general terms, on the future prospects for the development of plant quarantine procedure in the U.S.A.

After a short chapter giving a brief appreciation of the world situation, the author concludes with an Appendix summarizing the Federal Plant Disease Quarantines issued over the past 40 years, a list of 80 references and a short, but adequate index.

At 33*s* 9*d* the book is expensive, but the quality of production is excellent and the text remarkably free from typographical errors, only two of which were noticed, these on pages 62 and 197.—J.W.

THE SOUTH AFRICAN SUGAR YEAR BOOK

The South African Sugar Journal, Durban. 1954. 256 *pp.* (illus.) 10*s*

The 1953–54 edition of the South African Sugar Year Book maintains the new format and the more extensive character of last year's volume. This well illustrated and attractive book succeeds in giving a clear picture of the lively condition of the South African sugar industry. It may be effectively divided into two sections; the first is concerned with special articles, industrial reviews and progress reports of the experiment stations serving the industry and the second, with the statistics reflecting the industry's performance during 1953–54.

Pride of place is rightly given to an article dealing with the setting up of the new sugar factory at Pongola, which in effect extends the sugar industry to the extreme north of Zululand and the Transvaal side of the Pongola river. A task of herculean proportions has been carried out here, inasmuch as it involved the transfer to Pongola of an existing sugar factory 350 miles distant, its re-erection on a new site of bare veld and low scrub and the

building of a housing estate for labourers and senior staff, all in the space of 21 months. Other articles in the same section include those on weather conditions in the cane area, cane breeding, agricultural mechanization, a discussion of the factory reports from the industry for 1953–54 and the annual reports of the experiment station at Mount Edgecombe, which, incidentally, now has a fertilizer advisory laboratory attached to it, and of the Sugar Milling Research Institute at Durban. The statistical section of the book is clearly presented and among the points of interest that may be gleaned therefrom might be mentioned the fact that the industry produced a record crop of nearly three-quarters of a million tons of sugar during the year under review and that for the same acreage of cane as last year an average yield of 27·97 tons cane per acre was achieved as compared to that of 25·6 for last year. This alone has resulted in an increase of 60,526 tons in the sugar yield. It is also noteworthy that the Natal-bred cane, N:Co.310, now occupies 41 per cent of the whole area under cane.

As in the earlier volumes, details are given of the make-up both in the matter of finance and personnel of the companies and organizations in whose hands the South African sugar industry rests. These books are a useful guide to the progress of the South African sugar industry for those outside and a record of the achievements of those whose task it is to work within it.—L.F.W.

THE DEVELOPMENT OF TROPICAL AND SUB-TROPICAL COUNTRIES

Edited by A. Leslie Banks. Edward Arnold (Publishers) Ltd., London, 1954. 217 *pp.* 10 illus. 18*s*

'The Development of Tropical and Sub-Tropical Countries—with particular reference to Africa' embodies the verbatim discussions which took place at an informal seminar held at Cambridge University in the summer of 1953. Those attending, 32 in number, were drawn from a wide field and each was a specialist in his or her particular subject.

The complexities of the problems of development in the more backward areas of Africa are indicated not only by the varied and wide interests of those taking part, but also by the scope of the discussions which, starting with a broad survey of the inherent problems, developed into a review of such interrelated factors as power and water, food and its production, health and welfare, education and technological development. Throughout the discussions the underlying basic theme was, as it must be, the indigenous peoples themselves or, as one speaker put it 'the problems of development boil down eventually to the quality of the individual and the quality of communal life'. It is on this foundation of relatively primitive and preponderantly peasant agricultural peoples that there has to be built a modern society capable of feeding itself and capable also of attaining a standard of life and of economic progress adequate to maintain those services such as medical, educational and the like, which are essential for permanent welfare and development. The discussions give a detailed analysis of the various fundamental problems and suggest lines of approach; they place a proper

emphasis on the need for an adequate and balanced diet and hence on the fundamental importance of a sound and stable agricultural system against a tide of rising populations; and the sections which deal with these aspects are of particular interest. To one who has spent many years of his life working in some of those parts of Africa which are the subject of the discussions, there is perhaps but little that is new in an enumeration of the problems or of their interrelationship, but it is interesting to read this critical review of them and to obtain the views of experts in their own particular fields. Anyone who, for the first time, is starting to work in any capacity in Africa will find in this book a clear, authoritative and concise appreciation of fundamental problems of development on the solution of which depends the future well-being not only of Africa but, in a large measure, of the whole world.—A.B.K.

A DICTIONARY OF DAIRYING

J. G. Davis. 2nd edn. Leonard Hill Ltd., London, 1955. xxviii + 1,132 *pp.*, 348 illus. 65*s*

In 1950 the first edition of Davis' Dictionary of Dairying appeared. This work was prepared for use chiefly in temperate areas, but since little or no critical information concerning tropical dairying is as yet available, and that which is available is scattered in many publications, this volume has a real value for those working in the tropics. The writer has made so much use of his own copy of the first edition that it has had to be rebound.

The original edition has now been expanded and brought up to date. Most of the material has been compiled by Dr. Davis himself, but some contributions have been made by the relevant authorities on the subject. Those interested in dairying are extremely fortunate in having an encyclopedia available on their subject.

It is hoped that the references to the tropical products such as ghee will receive more attention in future editions, and that more reference will be made to tropical aspects of dairying in general. In spite of these limitations for the tropical worker one cannot but be thankful for the monumental work of Dr. Davis and his associates.—J.R.H.

PLANT REGULATORS IN AGRICULTURE

Edited by H. B. Tukey. John Wiley and Sons, Inc., New York; Chapman and Hall, Ltd., London, 1954. x + 269 *pp.* (illus.). 44*s*

As any branch of research expands it becomes increasingly difficult for any single individual to review the whole field and there is now an increasing tendency for reference books to be co-operative efforts by several workers, each dealing with one particular aspect of the problem. This book contains chapters by seventeen contributors, each a specialist in his field. There are obvious advantages to the method, but there may also be disadvantages, particularly in regard to overlapping and repetition. Considerable responsibility is thrown on the editor to avoid such faults and in this volume the editor has been singularly successful.

In his preface the editor stresses the rapid growth of the subject and the need of county agricultural agents and agricultural extension workers for a

simple exposition of the diverse roles which plant regulators play in agriculture. The term regulators is used rather than hormones or auxins which are defined as special types of regulators. The book is planned so that each chapter begins with the elementary facts and principles and advances to the more involved phases.

After chapters on the general principles of plant growth and how regulators act, the individual authors deal with their use in the rooting of cuttings, control of flowering and fruit setting, parthenocarpy and fruit development, fruit drop and blossom thinning, maturing and ripening, inhibition of sprouting and weed control. Each chapter is complete in itself and carries a modest but adequate bibliography.

In spite of the enormous amount of work that has been done on the subject, much of the practical application of regulators in agriculture results from ad hoc trials of a wide range of chemical regulators; and although their greatest use at present probably lies in the field of weed control their value in other fields of crop production will undoubtedly increase with greater knowledge. This book will be of great value in providing the background knowledge to a subject which superficially appears to be dominated by a large number of lengthy and forbidding chemical names. Its reference value is increased by a number of tables and the diagrams and illustrations are very well reproduced.—D.B.M.

TIV FARM AND SETTLEMENT

PAUL BOHANNAN. H.M.S.O., London, 1954. 82 *pp.* with charts, maps and diagrams. £1 7*s* 6*d*

The author has obviously collected information with meticulous attention to detail, and is to be congratulated on his success in obtaining so much knowledge concerning family structure and land tenure, both subjects on which it is notoriously difficult to obtain reliable information.

This publication is similar in form to a number of other reports published during recent years and collectively they present a picture of rural life, which in spite of minor differences is surprisingly similar. The area of land required for a family unit, for instance, is similar in most territories. Small scattered plots are a universal feature of peasant agriculture.

The concept of land ownership as understood in temperate region countries is quite foreign to all tropical African communities; this has, in the past, been the cause of much friction between European planters and their African neighbours.

The monograph can be thoroughly recommended as providing an unusually complete picture of an African peasant community.—W.J.B.

TITLE-PAGE AND CONTENTS LIST FOR VOLUME 32

The title-page and contents list of Volume 32 of this journal, of which this is the last number, will be issued with our number of January 1956 for the benefit of those who wish to bind it to complete the annual volume.

OBITUARY

Sir Harold Tempany, Kt., C.M.G., C.B.E., D.Sc., F.R.I.C.
(Governor of the Imperial College of Tropical Agriculture 1941–46)

Sir Harold Tempany, whose sudden death on 2 July, at the age of 73, came as such a shock to his many friends both in the Colonies and in the U.K., had a long and distinguished career in the Colonial Agricultural Service which was crowned by his tenure of office as Agricultural Adviser to the Secretary of State for the Colonies.

After being educated at the County School, Richmond, Surrey, and University College, London, where he trained as a chemist, Tempany was appointed Assistant Agricultural Chemist in the Leeward Islands in 1903, becoming Government Agricultural Chemist and Superintendent of Agriculture there in 1909. During the latter part of his service in the Colonies he was Director of Agriculture in Mauritius from 1917 to 1924 and was then appointed to one of the most important colonial directorships as Director of Agriculture, Straits Settlements and Federated Malay States. This post he held until 1936 when he retired from the Service and was appointed Assistant Agricultural Adviser to the Secretary of State for the Colonies. On the appointment of Sir Frank Stockdale as Comptroller of Development and Welfare in the West Indies in 1940, Tempany succeeded him as Agricultural Adviser and continued in that position until his retirement at the end of 1946. By virtue of his training and by natural inclination Tempany took a particular interest in research throughout his career both when serving in the Colonies and latterly during his tenure of office in the Colonial Office. For example, the establishment in Mauritius of the Sugarcane Research Station, recently converted into the Mauritius Sugar Industry Research Institute, was largely due to Tempany's influence, and during his time as Director of Agriculture in Malaya he extended considerably the agricultural research carried out in that territory. When Agricultural Adviser to the Secretary of State for the Colonies he was one of the first to appreciate the need for greatly increased research on cocoa in West Africa which was emphasized in the very early stages of the swollen shoot virus disease which has since devasted large areas of cocoa in the Gold Coast and Nigeria. It was largely as a result of his recommendations that the West African Cocoa Research Institute was established. Similarly, in East Africa the establishment since the war of the East African Agriculture and Forestry Research Organization with its headquarters near Nairobi in Kenya, replacing the former East African Agricultural Research Institute at Amani, arose directly from the recommendations of a mission which visited East Africa in 1946 comprising Tempany, Sir Frank Engledow and Professor J. W. Munro.

Tempany's long and distinguished service to colonial agriculture was officially recognized by the award of the C.B.E. in 1933, the C.M.G. in 1941, and a Knighthood in 1946.

Tempany was a man of boundless energy and meticulous in his attention to detail in everything he did, and after his retirement as Agricultural Adviser he maintained his contact with colonial and tropical agriculture by continuing to serve on the London Advisory Committee for Rubber

Research (Ceylon and Malaya), by his membership of the Advisory Committee in England of the West Indian Sea Island Cotton Association, of which he was chairman for a considerable period, and as a member of the Administrative Council of the Empire Cotton Growing Corporation. In addition he continued to serve as a member of the London Advisory Committee on Agricultural Research in the Sudan up to the time of his death. But these part-time activities could not satisfy Tempany's insatiable appetite for work and in 1946 he took over the editorship of a series of books on tropical agriculture which are being published by Messrs. Longmans Green & Company with the active encouragement of the Colonial Agricultural Advisory Council. At the time of his death he had almost completed a book on agriculture in colonial territories for this series and was actively negotiating the production by selected authors of additional books. The editorship of this series and the preparation of his own book failed to fill his time and in 1949 he accepted the editorship of *World Crops* which he lived to see established as an outstanding publication on world agriculture before relinquishing his editorship of the journal shortly before his death.

Tempany was a kind, courteous and considerate man with an extensive knowledge of tropical agriculture and possessed of an exceptionally good memory. Although a man of strong views, he was at all times ready to listen patiently in discussion and to modify his conclusions where necessary. He will long be remembered by many members of the Colonial Agricultural Service for his courtesy and hospitality to those who called on him whilst in the U.K. to discuss their agricultural problems in the various parts of the colonial empire, and his sudden death will be a source of sorrow to a wide circle of friends both at home and abroad.

Recent Publications of The Imperial College of Tropical Agriculture

Studies in West Indian Soils, XII: The Agricultural and Forest Soils of St. Lucia, by F. HARDY and G. RODRIGUES. 5*s*

Studies in West Indian Soils, XIII: The Agricultural Soils of St. Kitts-Nevis with Notes on Statia (Dutch), by F. HARDY and G. RODRIGUES. 5*s*

A Report on Cacao Research, 1945–1951. 132 *pp.* fully illustrated in colour and black and white. 25*s*

A Report on Cacao Research, 1952. 8*s*

A Report on Cacao Research, 1953. 10*s* 6*d*

Reprints are available, at varying prices, of articles in the Cacao Research Reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao (1945–1951 Report)—Price 5*s* plus postage.

Memoirs—Economic Series No. 2: Peasant Farming: Report on Peasant Experimental Farms at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., by A. L. JOLLY. 1*s*

Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the second world war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published :

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